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FELDSPAR
IN
PENNSYLVANIA

By

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LETTER OF TRANSMITTAL

Hon. James F. Woodward,
Secretary of Internal Affairs.

Sir:

I have the honor to transmit herewith a manuscript on Feldspar in Pennsylvania by Ralph W. Stone and H. Herbert Hughes, of this Survey.

The feldspar industry is one of the smaller industries of the State. During the first twenty years of this century the production of feldspar in this State amounted to 265,000 tons valued at \$1,990,000. Twenty years ago Pennsylvania ranked second among the States for crude feldspar production; ten years ago her production was sixth in quantity and fourth in value; in 1928, (the latest year for which figures are available at time of writing) Pennsylvania held eighth place with an output of only 2052 tons.

It is hoped that this report may reveal the situation as it stands today, and where supplies are still available.

Respectfully submitted,

A handwritten signature in cursive script, reading "Geo. H. Ashley". The signature is written in dark ink and is positioned above the printed title "State Geologist".

State Geologist.

May 3, 1928.

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FELDSPAR IN PENNSYLVANIA

By RALPH W. STONE AND H. HERBERT HUGHES

INTRODUCTION

Feldspar is a mineral used in making pottery and enamel ware. Pennsylvania has long been a producer, formerly more than now. Occasional inquiries regarding feldspar resources that could not be answered by the latest report, now 10 years old, and a desire on the part of the Geological Survey to keep abreast of the mineral developments in the State, prompted the field work on which this report is based.

The earliest report on the feldspar deposits in Pennsylvania is that of T. C. Hopkins,¹ based on field work in the summer of 1898, and published in the annual report of Pennsylvania State College 1898-1899. Six pages are given to a description of the quarries.

The next was by E. S. Bastin² of the United States Geological Survey, who visited all of the more important feldspar deposits in the State in May, 1907. His description covers 8 pages in a bulletin on the Feldspar Deposits of the United States.

About 1914 the United States Bureau of Mines conducted "an investigation of the feldspar resources of the New England and North Appalachian States with a view to greater efficiency and economy in their utilization." Watts³ gives 14 pages to a description of the development at 20 localities in Pennsylvania, and to firing tests on samples from most of them.

Mr. Stone visited most of these deposits early in September, 1927. For some of the descriptions he has been obliged to quote largely from the writings of others, because time has obliterated and vegetation has covered the exposures of former years. Both authors visited some of the deposits in April, 1928. Mr. Hughes wrote the description of the Elam, Fazio, Twin Oaks, Rigby, and Butler deposits and of the thin sections which he examined with a petrographic microscope.

The result of this investigation of the feldspar localities is the conclusion that the Pennsylvania deposits are not exhausted, that in all probability many pegmatite dikes remain undiscovered, and that No. 2 spar can be produced in quantity when the price is attractive to operators.

¹ Hopkins, T. C., The clays and clay industries of southeastern Pennsylvania.

Part I. The raw materials and their preparation: Appendix to Annual Report of Pennsylvania State College 1898-1899, off. doc. 22, pp. 7-20, 1900.

² Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, pp. 63-72, 1910.

³ Watts, A. S., The feldspars of the New England and North Appalachian States: U. S. Bur. Mines Bull. 92, pp. 145-158, 1916.

USES

Feldspar is a mineral produced in the United States largely in Maine, New Hampshire, Connecticut, New York, and North Carolina and used in the manufacture of pottery, enamel ware, enamel brick, and electrical porcelain. Pennsylvania is a small producer. The consumption in the United States is divided about as follows¹:

	<i>Per cent</i>
Ceramic industries	84.0
Roofing and cement surfacing	6.0
Cement manufacture	5.0
Scouring soaps and abrasives	2.5
Binder for abrasive wheels, etc.	2.0
Poultry grit	0.5
	100.0

In the ceramic industry the great use is as a constituent part of both body and glaze in true porcelains, white ware, and vitrified sanitary ware, and as a constituent of the slip (under glaze) and glaze in so-called porcelain sanitary ware and enamel brick. In the body of vitrified wares feldspar ranges from 10 to 35 per cent. It serves as a flux to bind the particles of clay and quartz together. Glazes contain a higher percentage, 30 to 50 per cent, of feldspar.

For use in making pottery it is required that feldspar be nearly free from any mineral that will not burn white; especially must it be free from iron-bearing minerals (biotite, hornblende, tourmaline, garnet, etc.).

Enamels applied to metals are fused with feldspar. Our modern gleaming white bathtubs and wash bowls are usually made of cast iron to which while still hot is applied an enamel containing much feldspar. It may enter into the manufacture of plate, window, and bottle glass as a source of alumina and of the alkalis, and with fluor-spar is commonly used in opalescent glass.

Small quantities of the purest grades of potash feldspar are used in the manufacture of artificial teeth. Several operators in Pennsylvania in former years have selected the best lumps or large crystals of microcline for this market. Dental spar, as the quarry men call it, used to bring the highest price, \$6 to \$8 a barrel of 350 pounds.

In some Portland cement plants where dust is collected to recover potash, the yield of potash is increased by the use of potash feldspar in the batch.

Crushed spar is used in considerable quantity in the form of granules on roofing material and also in the facing on cement blocks, particularly on those designed to resemble granite. For this purpose

¹ Katz, F. J., Feldspar: U. S. Geol. Survey Mineral Resources 1917: p. 141, 1920.

the feldspar of course need not be high grade; in fact a pegmatite from which the spar cannot be separated economically may be used for this purpose. Poultry grit is another use and outlet for low grade spar. It need only be crushed and screened to the size suitable to be attractive to poultry, one size for mature or large fowls and a smaller size for chicks.

Scouring soaps and abrasives made of feldspar differ from those made of quartz and other minerals in the degree of hardness of the individual grains. Feldspar is slightly softer than glass and so less liable to scratch windows or glassware than soaps in which quartz or other harder mineral is the abrasive substance.

A small quantity of feldspar is used annually for making carborundum, corundum, emery, and other abrasive wheels. The feldspar fuses and on cooling binds the abrasive grains together.

GENERAL DESCRIPTION

Feldspar, or spar as the miners call it, is a general name for a group of abundant rock-forming minerals. They are aluminosilicates of potassium, sodium, calcium, and rarely barium. Only four of the varieties are of commercial importance, microcline, orthoclase, albite, and anorthite.

Microcline, the principal commercial spar in Pennsylvania, is a triclinic potassium-aluminum silicate, $K_2O.Al_2O_3.6SiO_2$. Its color may be white, grayish yellow to cream, or some shade of red. Many of the larger crystals in Pennsylvania deposits are flesh pink to salmon.

Orthoclase is a monoclinic variety of the same composition as microcline. These two differ only in crystalline form and optical properties.

Albite is a sodium-aluminum silicate, $Na_2O.Al_2O_3.6SiO_2$. It varies in color from pure white to pale green.

Anorthite is a calcium-aluminum silicate, $CaO.Al_2O_3.2SiO_2$.

Albite and anorthite are the two ends of the plagioclase group of feldspars, which, with the intermediate members, show a regular gradation from much ^{soda} potash and no lime to much lime and no ^{soda} potash.

All of these varieties of feldspar show two principal cleavages intersecting at an angle of about 90° . The angle between faces in the potash spars, microcline and orthoclase, is practically 90° , but that in the plagioclase feldspars is 86° , a difference so slight that it is not readily recognized.

The cleavage faces have brilliant luster, some more brilliant than others. Albite and other plagioclases are distinguished from potash spars by faint, perfectly straight parallel lines or striations which are reflected in bright light on the most brilliant cleavage faces.

The variation in composition of feldspars and pegmatites is shown in the following table:

Results of analyses of Pennsylvania feldspars and pegmatites¹

D. J. Demorest, Ohio State University, Columbus, Ohio, analyst.

Character of sample	Deposit		Composition							
	Town or place	County	Ignition loss	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	K ₂ O	Na ₂ O	Total
Microcline	Darlington	Delaware	Per et., .12	64.70	Per et., 19.60	Per et., .03	Per et., .05	Per et., 11.87	Per et., 3.76	Per et., 100.13
Microcline pegmatite	Chester Heights	do	.33	73.35	14.60	.06	.06	9.11	2.00	99.51
Albite pegmatite	do	do	.42	74.60	15.66	.05	2.75	.65	6.33	100.46
Buff microcline	Mendenhall	Chester	.21	64.36	20.01	.20	.46	12.44	2.48	100.16
Albite pegmatite	do	do	.60	67.93	20.49	.30	2.60	.80	6.95	99.67
Graphie granite	New Garden	do	.30	72.39	15.57	.20	.13	9.55	2.27	100.41
do	Sadsburyville	do	.24	67.87	17.82	.15	.12	10.93	3.33	100.46
Albite	Sylmar	do	.83	67.47	20.05	.15	.24	.86	9.74	99.34

Watts, A. S., The feldspars of the New England and North Appalachian States; U. S. Bur. of Mines Bull. 92, p. 96, 1916.

Properties of Pennsylvania feldspar in standard porcelain mixture

D. J. Demorest, Ohio State University, Columbus, Ohio, analyst.

Location	Feldspar	Fuses at degrees C.	Fired at 1330°C.			Shrinkage, per cent
			Warping at 1330°C.	Color	Translucency	
Darlington	Microcline	1290	none	cream-white	0.87	13.4
Chester Heights	Microcline	1300	none	cream	0.86	11.8
Chester Heights	Albite	1300	slight	cream	0.79	10.4
Boothwyn	Albite-pegmatite	1310	none	cream	0.77	12.6
Microcline	Microcline	1300	none	cream	0.79	12.4
Brandywine	Microcline-albite	1310	none	cream	0.80	12.0
Mendenhall	Microcline	1300	none	cream-white	0.80	12.8
Mendenhall	Albite-pegmatite	1310	slight	cream	0.80	11.8
Embreeville	Albite-pegmatite	1290	slight	cream	0.78	12.2
New Garden	Graphie granite	1300	none	cream-white	0.78	11.8
Sadsburyville	Graphie granite	1290	none	light-cream	0.84	11.6
Chatham	Microcline	1310	none	cream	0.79	12.6
Carpenter	Microcline-pegmatite	1290	none	cream	0.75	11.0
Hicks	Pegmatite	1290	none	cream	0.75	11.0
Baker Station	Microcline-albite	1280	distinct	cream	0.59	11.2
Cooper	Microcline-pegmatite	1290	none	cream	0.74	11.6
Sylmar, Brandywine	Albite	1280	slight	cream-white	0.72	12.0
				cream-white	0.82	12.0

ASSOCIATED MINERALS

Feldspar deposits of the granitic type are essentially coarsely crystalline mixtures of feldspars and quartz, but the associated minerals other than quartz are important as their quantity and mode of occurrence influence greatly the commercial value of the pegmatite. The feldspars, quartz, and muscovite (white mica) are light colored minerals; black tourmaline and biotite (black mica) are the principal dark colored constituents. Garnet, magnetite, and green beryl also are usually present.

Quartz. An essential constituent of pegmatite and the commonest of all minerals, quartz (SiO_2) is white to gray, though it may be pale pink or purplish. It is transparent to opaque, so hard that it is not scratched by steel, has no regular cleavage faces, and breaks with conchoidal fracture. It may be intercrystallized with feldspar as graphie granite, less intimately mixed with it, or so cleanly separated from the feldspar as to form distinct bands. Some separate masses of quartz may be transparent to translucent six-sided crystals, and some may have a granular structure known as sugar quartz. Sugar quartz, noted particularly in the dikes near Nottingham, Chester County, is white and semiopaque, owing to minute bubbles of gas, principally water vapor, entrapped in the solidifying silica, and to innumerable fracture planes that make it easily reducable to sand.

Crude crystalline quartz that is free from iron-bearing impurities is utilized in making sandpaper and other abrasives, in the manufacture of pottery, high grade tile, and fused quartz ware, and for other purposes. Iron-stained quartz has no commercial value but is used occasionally as building stone and road metal.

Muscovite. The small, glistening, colorless to pale yellow or light brown flakes occurring commonly in pegmatite and known as isinglass when found in large flakes, are muscovite or white mica. This mineral, a silicate of aluminum and potassium, is easily recognized by the ease with which it may be split into paper-thin, transparent, flexible and elastic plates. It is so soft as to be scratched by the fingernail. It may be found in large crystals (the largest seen by the writer in a Pennsylvania feldspar quarry was 8 inches in diameter), it also occurs as a massive segregation of small plates, particularly along the wall of a dike, or it may be disseminated throughout the dike.

Muscovite in clear, unflawed plates from which perfect pieces at least 2 inches square can be cut is marketable for electrical and other commercial uses at a good price, but mica of this character has not been found in Pennsylvania. Large crystals or books of mica are rare and almost invariably are so flawed, ruled, or stained as to be valueless. Where the muscovite is segregated in bands or humps, it can be separated from the feldspar in quarrying or by cobbing, but where it is

scattered through the pegmatite it is inseparable and if very abundant the spar cannot be used for making pottery.

Biotite. Biotite (black mica) is similar to muscovite in physical properties but is dark brown to nearly black, and somewhat less elastic. It is a silicate of potash, iron, and magnesia and has no commercial value. Unlike muscovite even a little of it, because of its iron content, makes feldspar unsuited for white pottery and enamel. Biotite is either present in abundance or practically absent in pegmatite. Where abundant it is likely to be in large crystals and can be separated from the feldspar.

Tourmaline. A shiny black mineral in the form of rods up to a foot long and found not uncommonly in pegmatite is tourmaline. It is a complex aluminum silicate of hexagonal crystallization containing boron and in some varieties either iron, magnesia, or the alkalies. It is not scratched by steel, has uneven fracture, is vitreous, and that found in Pennsylvania feldspar deposits is so black that it looks like anthracite. It must be completely removed from feldspar that is to be used for pottery.

Garnet. The variety of garnet commonly found in feldspar deposits is deep wine-red, nearly equidimensional, and ranges in size from mere specks to much fractured translucent crystals 2 or 3 inches in diameter. As andradite, the common garnet, is a calcium iron silicate its presence in feldspar is highly objectionable, for the iron in the garnet will discolor the fused feldspar. Accordingly to Watts¹ the addition of 1 per cent of garnet to feldspar that fuses to milky white causes it to fuse to an intense yellow brown, and the presence of 0.1 per cent of garnet makes a feldspar unmarketable for use in pottery. Garnet is not readily detected in the quarry, especially when it occurs as small crystals in pink spar. If the garnets occur in well defined bands they may be eliminated, but if they are scattered through the pegmatite the expense of removing them by cobbing is too great and the result too uncertain.

Beryl. A glucinum-aluminum silicate, $3\text{GfO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$, used as a gem when clear and well colored. It is transparent to slightly translucent, harder than feldspar, and has a subhoneycombed to uneven fracture and vitreous luster like feldspar. It occurs usually in hexagonal crystals in masses of pure feldspar. The usual color is pale blue, but beryl may be golden, green, or even pink. Blue green beryl is called aquamarine, and bright green is emerald. To be of value for gems it must be free from flaws and perfectly transparent.

The presence of beryl in feldspar makes the fused product opaque and so tends to reduce the translucency of the ware. Therefore it is objectionable and must be eliminated. The only practical way of

¹ Watts, op. cit., p. 27.

doing this is by watching for it in the quarry and sorting out the beryl-bearing rock. A pale green beryl intensely flawed occurs in the Fazio quarry near Embreeville.

Crystals. Pegmatite, the igneous rock in which commercial deposits of feldspar is found, is also known as giant granite. As this name indicates pegmatite is like a very coarse-grained granite. The coarseness however ranges from little larger than that of granite to rock with feldspar crystals several feet across. The coarsest pegmatite seen by the writer in Pennsylvania contained feldspar and quartz crystals about 8 inches in diameter. Muscovite most commonly is in flakes only a fraction of an inch across, those 3 inches across are rare and an 8-inch crystal from the Carpenter quarry near Avondale was exceptional. Tourmaline crystals, seen in the Barrens of Nottingham Township, Chester County, were about $\frac{1}{8}$ -inch in diameter and 2 or 3 inches long. The largest tourmaline observed was about one foot long, and $2\frac{1}{2}$ inches in diameter, in the Fazio quarry near Embreeville.

Unlike granite, the crystals or grains of feldspar or quartz in any one spot are not all approximately the same size; in pegmatite adjacent feldspar crystals may vary by many diameters, half inch crystals being associated with others several inches in diameter.

Graphic granite. Graphic granite is a rock composed of feldspar and quartz in which the quartz is so disposed in the feldspar that in cross section it has some resemblance to Hebrew and cuneiform writing, and from this derives its name. There are fine-grained and coarse-grained phases, but evidence points to a nearly constant proportion of 70 to 80 per cent feldspar and 20 to 30 per cent quartz.

As much of the material mined for feldspar is graphic granite, and the finer-grained graphic granite appears to contain a larger percentage of quartz than the coarser kind, the fact that whether coarse or fine, the proportion is about the same, is of economic importance. A certain amount of pure feldspar added to graphic granite reduces the percentage of quartz in the ground product to the standard grade. Consumers should think of graphic granite as approximating 74 per cent feldspar and 26 per cent quartz, from which figures it will vary only slightly. It needs therefore only a moderate amount of pure spar to bring graphic granite up to ceramic requirements.

GEOLOGIC OCCURRENCE

Although feldspar is a principal constituent of igneous rocks, it is rarely in sufficiently large crystals or readily separable from other minerals to be of commercial importance. In some granitic rocks feldspar is 60 per cent of the mineral aggregate but the grains are so small and so intimately mixed with other minerals that the rock

has no value as a source of feldspar. The common source of feldspar is pegmatites—igneous rocks of very coarse and irregular texture. These rocks vary widely in mineral composition but only two types yield spar of commercial importance: (1) the granite pegmatites, which are the same as granite except that the grains are very much larger, and (2) the soda pegmatites, which consist of soda feldspar (albite) and a small quantity of hornblende, but contain no quartz or tourmaline. Most feldspar quarries are in granite pegmatite, but a very few in Pennsylvania and Maryland are in soda pegmatite.

Pegmatites are usually considered to represent the final stage of solidification of molten magma. Their occurrence in Pennsylvania, with rare exceptions, is limited to the area of crystalline rocks in the southeastern part of the State. (Figure 1.) This residual molten

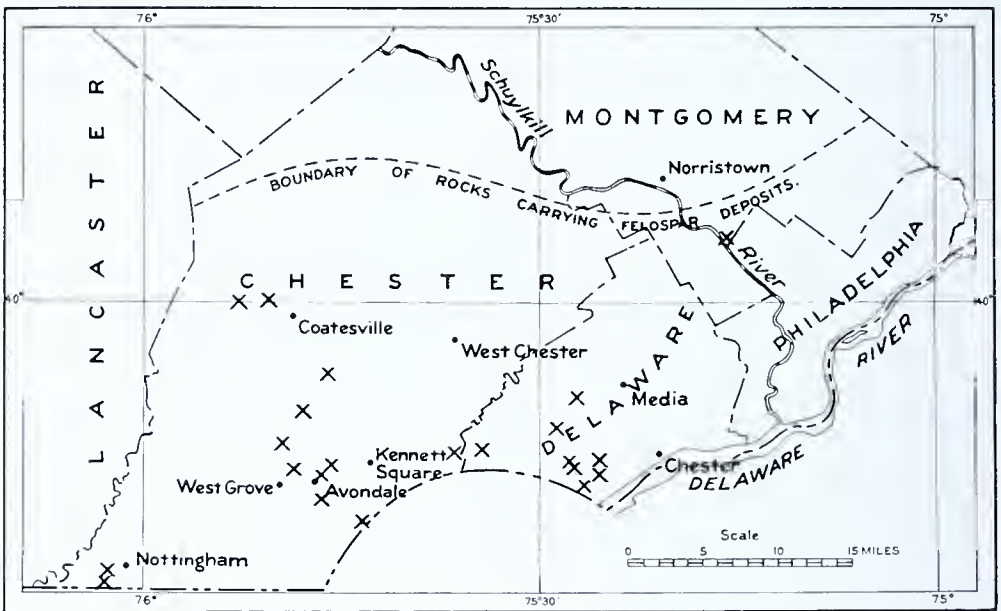


Figure 1. Map showing area in which pegmatite dikes may occur

liquid is similar to granite magma save that it contains a concentration of some of the rarer constituents which accelerate the growth of crystals during crystallization. The coarsely crystalline character of most pegmatites, then, is due to the catalytic action of fluorine, boron, chlorine, tungsten, or similar constituents although none of these elements are found in the resultant crystals. Such elements are called mineralizers. The molten magma of the pegmatite was forced into cracks or opened and filled lines of weakness in the country rock. As a result, the pegmatites are irregular in shape and usually noticeably lenticular. These intruded masses are known as dikes and sills, depending on whether their position is more nearly vertical or horizontal. A dike or sill may have considerable length but pinch and

swell along its course. For instance, a pegmatite dike may be 1,000 feet long and not more than 2 or 3 feet wide throughout much of its length, but swell at a few places to 50 feet or more.

Pegmatite dikes and sills vary widely in character. The rock may be of a comparatively uniform texture throughout, or it may consist of a number of distinct and separate bands of widely differing composition. In the first case the dike represents a single fluid or molten intrusion, but a banded dike indicates several distinct periods of solidification. The contact with the inclosing walls may be indistinct, as if the dike had been intruded before the walls were completely solidified or as if the intruded material had slightly melted and blended with the wall rock; or the contact may be very sharp and distinct.

If the crystallization is very coarse or the dike consists of distinct bands, feldspar may be obtained in commercial quantity quite free from other minerals. In most dikes, however, feldspar and quartz are intimately intergrown, and fairly pure spar can be obtained only by careful elimination of such associated minerals as occur in lumps.

Not only are pegmatite dikes very irregular in shape, as is to be expected of a mass intruded under varying pressure into rock differing in density and kind, but also the structure of a dike is variable. Coarsely crystalline pegmatite, almost exclusively feldspar and quartz, may change abruptly to a finely crystalline rock containing several other minerals which render it valueless as a source of commercial feldspar. In the larger bodies of pegmatite may be found large bodies or horses of the wall rock, which must be omitted in mining or discarded. A pegmatite dike may be remarkably clean or free from impurities in the upper part and change at a depth of 15 feet or so to granite carrying biotite and hornblende, or the cap of a dike may be valueless for commercial feldspar but at a depth of two or three feet under the surface may be excellent material. Also a dike may be many feet wide but composed of different bands, some of clean feldspar, some almost wholly of quartz, and some heavily charged with mica. In this case only a small portion, two or three narrow bands out of the whole width, may be worth mining for spar.

As pegmatite is generally conceded to come from the subterranean mass of molten material which on cooling formed granite, so it is natural that most pegmatite dikes are in granite or granitic rocks. The crevices, however, into which the pegmatite was intruded may extend beyond the granite mass into other kinds of rock.

PETROGRAPHY

During the megascopic examination of samples of feldspars from quarries mentioned in this report some doubt was encountered as to the exact identity of a few of the specimens. Since the study of the

optical properties is the only certain means of identification it was deemed advisable to have thin sections* made of the questionable samples. From their study it is impossible to attempt a thorough petrographic report on the feldspars of southeastern Pennsylvania but they do show some rather interesting facts which we may add to our knowledge of Pennsylvania geology.

Petrographically, the feldspars of importance in the quarry district are microcline, orthoclase, the plagioclase group, and perthite. Microcline (KAlSi_3O_8) is found in many localities in the form of unaltered fragments of varying sizes showing well developed cross hatching or gridiron structure. The only typical orthoclase examined was the thin section from the Meredith quarry, although it occurs in small crystals as a partial constituent of several of the sections. Orthoclase has the same chemical formula and many physical properties the same as microcline. In the thin section, however, they are easily distinguished as shown by contrasting Plates X-XI with Plate IX, B.

The end members of the plagioclase group, albite ($\text{NaAlSi}_3\text{O}_8$) and anorthite ($\text{CaAl}_2\text{Si}_2\text{O}_8$), are isomorphous to the fullest sense of the term; that is, the chemical composition may vary with only a very small change in the crystal form. No definite boundary can be established between any two members of the group for the two compositions may unite as solid solutions in every proportion. The result is a gradual gradation from one to the other. The following limits¹ may be adopted to identify the six most common members of the group:

Albite		albite	+	anorthite ₀	to	albite ₆	+	anorthite ₁
Oligoclase		albite ₆	+	anorthite ₁	to	albite ₃	+	anorthite ₁
Andesine		albite ₃	+	anorthite ₁	to	albite ₁	+	anorthite ₁
Labradorite	...	albite ₁	+	anorthite ₁	to	albite ₁	+	anorthite ₃
Bytownite		albite ₁	+	anorthite ₃	to	albite ₁	+	anorthite ₆
Anorthite		albite ₁	+	anorthite ₆	to	albite ₀	+	anorthite

From their physical appearance or from chemical analyses there is no way to determine the position in the table of the various specimens. Optically, however, they may be classified by noting the extinction angle of the fragments in the thin section. In the ordinary thin section where the orientation of the grains is unknown it is impossible to attempt a technical method of measuring the angle. A fairly accurate classification can be made by measuring the angle between the twinning striations and the position of total extinction and locating its position in the following classification: albite, 4° to 16° ; oligoclase, 0° to 4° ; andesine, 17° to 30° ; labradorite, 30° to 40° ; bytownite, 40° to 50° ; anorthite, 50° —.

* A thin section is a rock sample ground to paper thinness (.03 m. m.) and mounted on a glass slide; 8,500 of these polished sections would make a stack only an inch high.

¹ Phillips, A. H. Mineralogy, p. 414.

In the sections examined the range of extinction angles was from 0° or parallel extinction up to about 20° or a little above. This indicates that the plagioclase feldspar found in the quarry material is principally from the albite end of the series.

Perthite, an intergrowth of orthoclase or microcline with plagioclase, is a common feldspar constituent of pegmatite rocks in southeastern Pennsylvania. The most prevalent occurrence is microperthite in which the intergrowth is so minute that its character is not recognized except by the aid of a microscope (Pl. V, A). In some specimens the microperthitic material makes up most of the section and in others it appears to occur as injected material filling cracks and weaker portions of the predominate mineral (Pl. X, B and XI, A). Several authorities* have discussed the nature of these perthitic intergrowths and the general consensus of opinion at present seems to account for their formation by a process of replacement and injection during end stage crystallization of the magma. Some of the sections examined show evidences of such a process, at least noticeable enough to warrant further investigation if additional proofs of such processes are being sought. Another perthitic intergrowth known as cryptoperthite refers to the intermixture of orthoclase and plagioclase in such a minute union that the individual feldspar fragments are indiscernible even with a high power microscope. Three of the sections examined seem to show this cryptoperthite. The plagioclase of the perthite is usually oligoclase although all gradations to albite occur; the more basic members of the group are almost unknown in these samples. From the ceramic or the chemical viewpoint, then, perthite is the equivalent of orthoclase or microcline to which has been added either albite or oligoclase in varying quantities depending upon the ratio of orthoclase to plagioclase in the intergrowth.

There is a marked absence of accessory minerals in microscopic sizes; biotite and other detrimental accessories usually occur in quantities segregated in definite parts of the dike. Secondary alteration, particularly the breaking down of the feldspars to form sericite $[(H_2KAl_3SiO_4)_3]$ and kaolin $(H_4Al_2Si_2O_9)$, is quite evident in much of the material. These minerals unless well developed are not undesirable because the alteration products are nearly equivalent chemically to the original feldspar. Completely altered material, however, would have entirely different properties; in fact, commercial deposits of kaolin are the result of the alteration of feldspars or related minerals.

* Allings, H. L. The mineralography of the feldspars: Jour. of Geol., vol. XXIX, p 193, 1921; vol. XXXI, p. 282, 1923.

Colony, R. S., The final consolidation phenomena in the crystallization of igneous rocks: Jour. of Geol., vol. XXXI, p. 169, 1923.

Iddings, J. P., Igneous rocks.

Kemp, J. F., The pegmatites: Econ. Geol., vol. XIX, December, 1924.

Winchell, A. N., Elements of optical mineralogy.

Photomicrographs and descriptions of the thin sections accompany the descriptions of the quarries from which they were taken. Unfortunately, sections from all the quarries are not available but in many instances one section is undoubtedly typical of several quarries in the same locality.

MINING

Practically all production of feldspar in Pennsylvania has been by simple open pit methods. In only two localities, (Brandywine Summit and Chatham) was underground mining done by drifts; a prospect drift is reported as having been driven in the pegmatite dike at Avondale.

Simple pits sunk on the outcrops or cuts made along a dike will describe most of the developments. In a few places work has continued until a hole has been made a hundred yards long and so deep that derricks were required for hoisting.

In Pennsylvania and Maryland, unlike New York and the New England States, the feldspar localities are unglaciated and the surface exposures are deeply weathered. This permits excavation with pick and shovel, and in most of the deposits this is the only method that has been used.

In 1927 the quarry south of Embreeville was worked by sinking vertical drill holes behind the face, and blowing it down, as in quarrying for crushed stone. The larger lumps are then broken by sledge or by dynamite. The ore is loaded by hand into quarry cars and run out on top of the waste pile. Here the material is sorted; waste goes over the dump and the ore is piled near the edge. The ore is broken with a light sledge or hammer to remove the waste and sort out the marketable spar. The sorted spar is piled on the levelled top of the waste dump where it is exposed to the weather and cleaned by rain until a carload has accumulated.

At the Baker quarry the rock is brought down by pick and bar, mauled when necessary, and loaded on a wheelbarrow, by which it is moved to a stock pile on the quarry floor. Little sorting is done because most of the rock is second grade spar, and that not fit for grinding is left in place.

MILLING

The one grinding mill, that of the American Feldspar Co., at Toughkenamon, alongside the Maryland Division of the Pennsylvania Railroad after running for many years, was destroyed by fire in 1928. Spar brought to the mill by truck was stored under a shed until needed. It was ground in a stone chaser mill, from which it went to three pebble mills. According to Robert R. Jacobs, who ran the mill, the

spar was pulverized until 85 per cent would pass a 325 mesh screen. The finished product was sacked and shipped for use in pottery and enamel ware.

A chaser mill consists of two buhrstone wheels about 3 to 5 feet in diameter and 12 to 18 inches thick, attached to each other by a horizontal axis, as are the wheels of a cart. The horizontal axis is attached at its middle to a vertical rotating shaft, which causes the buhrstone wheels to travel over a buhrstone bed, the feldspar being crushed between the wheels and the bed. The material as it comes from the chasers is screened, the tailings being returned to the chaser mill for re-crushing, while the fines go to the tube mills for their final grinding. The tube mills consist of steel cylinders revolving on a horizontal axis. They are usually lined either with hard wood blocks or with blocks made of natural or artificial siliceous bricks, and are charged with flint pebbles 2 to 3 inches in diameter.

The Sparvetta grinding plant had three 7-foot buhrstones set flat on the ground on masonry foundations, and the chasers were 5-feet in diameter. These stones, still at the mine, are coarse quartzose sandstone with quartz pebbles ranging in size up to half an inch or more.

PRODUCTION

According to the U. S. Geological Survey, which began to get fairly complete figures of feldspar production about 1900, the output in Pennsylvania in the first 20 years of this century was about 265,000 tons, and brought the producers and local grinding mills over \$1,990,000. The average annual production in those years was about 13,000 tons, and the annual income about \$100,000.

Since 1920 the industry has decreased. Some present and former producers say that with the present high cost of unskilled quarry labor, there is no profit in mining feldspar at present prices. The writer believes that this mineral resource is not exhausted, that some of the deposits still contain as much unmined spar as has been taken from them; that other commercial bodies of spar remain undiscovered in this same region, and that a natural resource capable of yielding \$100,000 annually to a few small communities is worthy of further consideration.

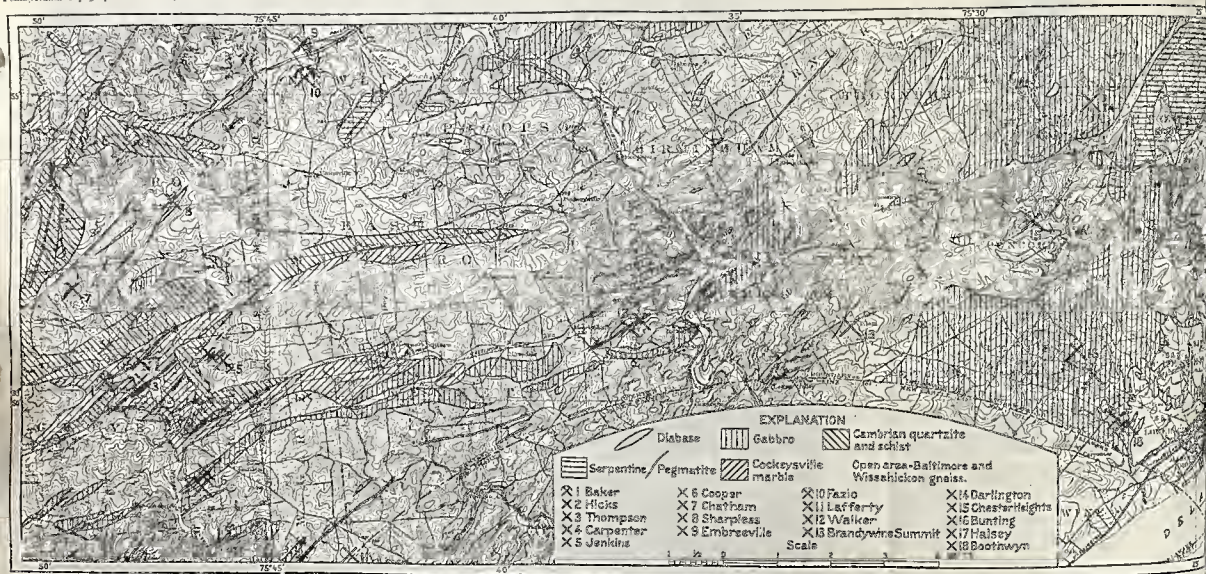
The accompanying table compiled from Mineral Resources of the United States, shows the annual production of crude and of ground or refined feldspar. The average price for crude spar was a little over \$3.00 a ton for many years, but fell to \$2.50 in 1915, and rose to \$9.47 in 1920. In 1925 it was \$3.55,

Production of feldspar in Pennsylvania, 1902-1928

Year	Crude			Ground			Crude and Ground	
	Tons	Value		Tons	Value		Tons	Value
		Total	Avg.		Total	Avg.		
1902	6,388	\$19,923	\$3.12	8,733	\$95,776	\$10.96	15,121	\$115,699
1903	4,485	14,396	3.21	9,066	78,509	8.66	13,551	92,905
1904	3,758	9,770	2.60	17,319	136,384	7.87	21,077	146,154
1905	*	*						
1906	4,604	17,695	3.84	13,863	114,535	8.26	18,467	132,230
1907	7,367	28,169	3.82	12,266	108,679	8.86	19,633	136,847
1908	3,616	13,226	3.61	10,473	90,276	8.62	14,089	103,502
1909	9,103	30,667	3.30	9,470	81,399	8.59	18,573	111,466
1910	3,751	12,611	3.36	11,340	92,140	8.12	15,091	104,751
1911	2,967	9,078	3.06	10,317	92,012	8.92	13,284	101,090
1912	1,947	4,985	2.56	7,504	66,302	8.83	9,451	71,287
1913	3,685	19,454	5.28	5,944	56,397	9.49	9,629	75,851
1914	2,843	10,162	3.57	7,258	61,231	8.44	10,101	71,393
1915	*	*		*	*		6,395	47,025
1916							7,342	56,323
1917	8,939	48,786	5.45				10,013	91,208
1918	4,389	27,651	6.30				4,916	57,269
1919							*	*
1920							8,562	81,104
1921	*	*		*	*		*	*
1922	*	*		*	*		*	*
1923	2,069	6,355	3.07	*	*		*	*
1924	1,481	4,763	3.22	*	*		*	*
1925	1,330	4,722	3.55	*	*		*	*
1926	1,484	4,492	3.03	*	*		*	*
1927	3,938	24,257	6.14					
1928	2,052	8,851	4.31					

* Figures not published because to do so would reveal individual production.

In 1907 Pennsylvania ranked second among the States for quantity of crude feldspar produced. Ten years ago her product was sixth in quantity and fourth in value. In 1928 (the latest year for which figures are available at the time of writing) Pennsylvania holds eighth place with an output of 2,052 tons, as against 105,560 tons for North Carolina, and 210,811 tons for the United States. Her output therefore is less than one per cent of the country's output.



GEOLOGIC MAP OF PRINCIPAL ALLEGHENY AREA IN CHESTER AND DELAWARE COUNTIES, PENNSYLVANIA
Geology by W. Bascom, E. B. Knopf, and A. J. Jones

In 1917 the prices for Pennsylvania crude ranged from \$2 for grits to \$6 for the better grades of pottery spar, with the average price well over \$5. Ground spar sold from \$7.20 to \$12 and averaged \$10.25. In 1925 the average value of all crude spar produced in Pennsylvania was \$3.55 a ton, or \$3 less per ton than the average value in Connecticut, New York and North Carolina, and as compared with \$9.04 for Maine and \$7.08 for the United States.

Grinding adds much to the value. The average value of ground domestic feldspar at the mill in recent years has been between \$16 and \$17. In 1925 Tennessee sold one-third of the country's output of ground spar at an average of \$12.95 per ton, New Jersey 21 per cent at \$19.41 and Maine 14 per cent at \$18.76. Pennsylvania's figures cannot be published without revealing individual mill production.

About 25,000 to 35,000 tons of crude feldspar is imported annually from Canada, at an average value near \$8 per ton. Most of this spar is ground in New York State. A small quantity of Canadian spar was ground in the mill of the American Feldspar Co., at Tonghkenamon, in 1925.

DESCRIPTION OF DEPOSITS

The feldspar deposits of Pennsylvania so far as known are all in the southeastern corner of the State in or adjacent to Chester and Delaware counties. All that have been described by other writers have

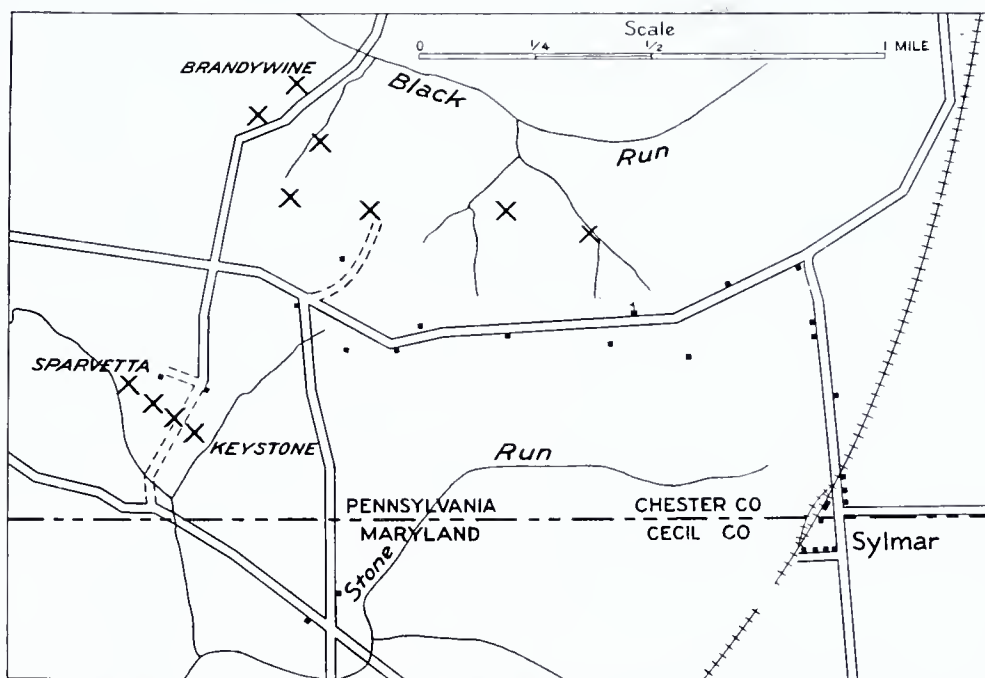


Figure 2. Map of feldspar quarries in the Barrens, West Nottingham Township, Chester County

been visited as well as several other deposits not previously described. There are about twenty-five, of which about twenty are in Chester County and the others in Delaware County. This description will proceed from west to east beginning with the southwest corner of Chester County.

CHESTER COUNTY

West Nottingham Township

In the extreme southwest corner of West Nottingham Township and between two and three miles southwest of Nottingham Post Office in an area known as "The Barrens" is a group of feldspar deposits that has been worked for many years and still is producing feldspar in a small way (Figure 2). The principal operations were concluded 25 or



Plate II. Sparvetta feldspar quarry

30 years ago. The largest deposits in this group are known as the Sparvetta, Keystone, and Brandywine.

Sparvetta quarry. The large open pit known as the Sparvetta quarry (Plate II) and operated formerly by the Sparvetta Mining Company is located 3 miles southwest of Nottingham and $1\frac{1}{2}$ miles west of Sylmar, Maryland. It is $\frac{1}{4}$ mile north of the State line on the head of a small branch of Stone Run. This is one of a group of openings apparently on the same feldspar vein which extends in a $N.55^{\circ}W.$ direction. The Sparvetta quarry, although described both by Bastin and Watts as being an open pit 400 or 500 feet long, was found by the writer to be 310 feet long and 150 feet wide. Southwest of it 150 feet is another pit about 50 feet long, and if these two were formerly continuous and have subsequently been separated by filling, the reported length of 500 feet is accounted for. The Sparvetta quarry now filled

with water is said to have a maximum depth of 80 feet. According to Bastin¹ the quarry taps two nearly parallel feldspar masses of different dip, "the dip of one being approximately vertical, while that of the other is so inclined that it joins the first near the bottom of the quarry to form a single vein. The southwestern of these two feldspar masses is only 5 to 10 feet wide near the surface but broadens downward. There is no evidence that the pegmatite dies out for some little distance in either direction along its trend, and presumably it also continues downward to a considerable depth. The wall rock is serpentine, dark green to nearly black in color. At the contact between the pegmatite and the serpentine within a zone that is for the most part about a foot wide, tale and some fibrous serpentine are commonly developed, the fibers of the serpentine being oriented perpendicular to the contact and being mostly 1 inch to 1½ inches in length. Neither of these minerals is utilized commercially."

Quarrying was done by steam drilling, blasting and hoisting by



Plate III. Buhstones, waste piles, and ruins of mill at Sparvettä quarry
 derricks and the spar was delivered to a mill beside the quarry. Here it was heated in a continuous feed kiln and then sprayed with cold water. This operation shattered the spar so that it ground more easily. It was then crushed in three chaser mills of the usual type and ground in tube mills. At the present time the ruins of the old kiln and the stones of the chaser mills are all that remain (Plate III). The kiln was built of serpentine with red brick corners. The mill-stones are of coarse grit or fine conglomerate consisting of white quartz pebbles imbedded in a coarse sandstone. Three of these stones 7 feet in diameter and set flat in a concrete foundation, and 7 other stones 5 feet in diameter remain intact. Two other stones used in the chaser

¹ Bastin, op. cit. p. 65.

mill are broken. The flint pebbles used in the tube mill can still be found scattered around the premises. It is reported that the capacity of the mill was about 25 tons in 12 hours.

The rock in these veins is not a granite pegmatite like that in most of the other deposits in Chester and Delaware counties, but a soda pegmatite, the principal minerals being soda feldspar (albite or oligoclase) and hornblende. Because the quarry has been idle for many years and is full of water nothing can be determined about the character of the vein from examination of the present walls. However, in the large dump (Plate IV) on the southwest side of the pit



Plate IV. Waste piles at Sparvetta quarry

which is 20 to 30 feet high, one can find abundant small pieces of white, pink and gray spar. This material is used occasionally at the present time for surfacing walks and driveways.

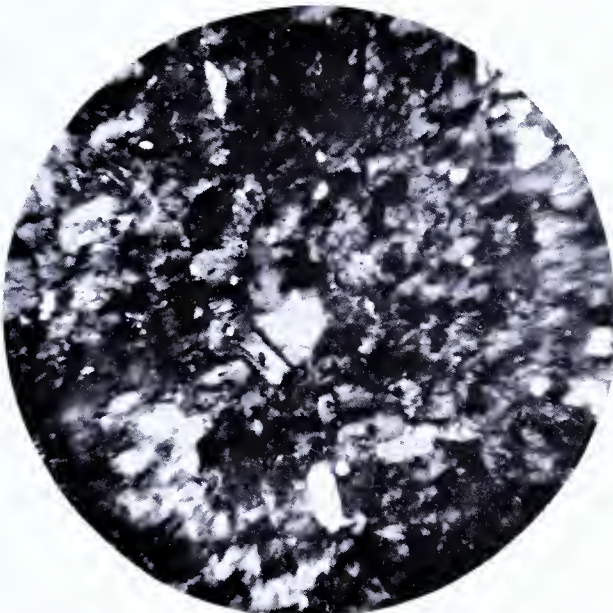
The thin section of the sample from the Sparvetta quarry (Plate V, A) consists of a micropertthitic intergrowth of orthoclase and plagioclase feldspar which is speckled with a few small quartz grains. All of the plagioclase fragments have the same orientation and, as a result, extinguish simultaneously. The extinction angle is quite small; in fact, it may readily be termed parallel extinction. This indicates that the feldspar is oligoclase rather than albite. The orthoclase occurs in irregular blotches and it is noticeably cloudy which is caused in part by the process of kaolinization, a common secondary alteration of feldspars to kaolin. The white spots on the picture are the quartz grains whose relative size is quite apparent. There is an occasional small flake of muscovite which is undoubtedly primary. Sericitization seems not to have affected the rock as yet although there are slight traces of its development. There are no noticeable microscopic accessory minerals in this section although it is evident that they are present in other parts of the quarry.

The rock has not been fractured to any appreciable extent; the large crack shown in the picture was probably formed during the grinding of the slide. This section seems to be typical of the product

PLATE V



A. Microperthite; oligoclase, showing twinning striations; orthoclase, the grey semi-altered material; quartz, light patches. Sparveta quarry, Chester County, Pennsylvania. X80 Crossed nichols. Exposed ten minutes, artificial light



B. Remolecularized feldspar; with a few fragments of plagioclase. Brandywine quarry, Chester County, Pennsylvania. X80 Crossed nichols. Exposed fifteen minutes, artificial light

from the Sparvetta quarry: a microperthitic intergrowth of oligoclase with a little orthoclase, in which is contained a minimum of quartz and other minerals whose presence is detrimental.

As already mentioned 150 feet southeast of the Sparvetta quarry is a pit 50 feet long on the same vein and 10 feet between walls. It is also full of water. 400 feet farther along the same southeast course is a kidney-shaped pool measuring about 50 by 75 feet and 400 feet still farther across the field in a southeast direction and just east of an old road is the Keystone quarry.

Keystone quarry. A large open pit about 300 feet long and 150 feet wide and now full of water is the quarry formerly operated by the Keystone Feldspar Company of Philadelphia. This pit like the others has its maximum length from northwest to southeast along the course of the vein and is reported to have a maximum depth of 80 feet. The spar here is said to be in a single vein and is similar to that of the Sparvetta quarry. The wall rock also is serpentine. According to Bastin the amount of material here seems to be large and there is no indication of its dying out for some distance either downward or along its course. The quarry when working was equipped with a steam hoisting engine, two derricks, a steam pump and steam drills, and employed a crew of 15 to 20 men. The ore, instead of being milled on the property like the spar produced at the Sparvetta quarry, was hauled to Sylmar station and sold to other mills in a crude state.

Where the vein shows above water level the bank of the quarry is vertical, and where the bank slopes only soil is seen, so no close examination could be made of the spar in the ledge. The long dumps on the south side of the pit are 10 to 15 feet high and contain more or less spar of the same character as that of the Sparvetta quarry. More muscovite and hornblende seem to have been found here, however. No machinery remains on the property nor have the dumps been worked over for the spar formerly wasted. The Keystone Feldspar Company suspended operations in 1908.

Brandywine quarry. Two miles southwest of Nottingham and not far from the south bank of Black Run on the west side of a road and half a mile north of the road forks is a large pit known as the Brandywine quarry because it was worked by the Brandywine Summit Kaolin and Feldspar Company. This pit is about 200 feet long and according to my rough measurement 60 feet wide. It has been reported as 90 to 100 feet deep but Mr. Rhodewalt, who is familiar with the property, says that the former superintendent told him the greatest depth is 115 feet. This quarry is on a single dike which is about 12 feet wide at the south end of the pit but broadens at the north end and has a direction N.10°W. The wall rock is serpentine and the contact is marked by a wall about 1 foot thick of blue-green talc now much decomposed. When Bastin visited the locality in 1907 the equipment consisted of derrick, steam hoisting engine, steam pumps and drills,

and from 15 to 18 men were employed. He concludes that the vein probably extends both to the north and south beyond present exposures and that the deposit can be assumed to extend to greater depths. Part of the output was sold to the Sparvetta Mining Company and hauled to their mill for grinding, and the remainder was hauled to Sylmar for shipment to the mill of the operating company near Brandywine Summit. In 1927 the pit was full of water to within 15 feet of the surface and as the walls are practically vertical the ledge itself could not be examined. The dumps are on the north or downhill side of the quarry and show in a way the character of the product. Like the Sparvetta and Keystone quarries the feldspar here is of the soda variety (albite) occurring generally in crystals from 1 to 2 inches across, though some are much larger. The crude feldspar shades from white through cream to gray. So far as observed quartz is absent in the pegmatites at these three localities. The principal iron-bearing mineral is hornblende which is nearly black as seen in the quarries. It is an aggregate of slender crystals, many of them radially arranged, which occupy spaces between the feldspar grains. Muscovite or white mica occurs in certain portions of the pegmatite, intergrown with feldspar so as to form more or less rounded aggregates 5 to 6 inches across. Most single plates of mica are not more than $1\frac{1}{2}$ inches across. Small garnets may be found associated with the feldspar.

The dumps at the Brandywine quarry contain so much spar that portions have been worked over and a considerable quantity of second grade spar has been obtained and shipped to grinding plants. Recently some also has been utilized for surfacing private roadways and a considerable tonnage is still available for this purpose.

A small part of the thin section of the Brandywine feldspar is quite similar to the micropertthite of the Sparvetta quarry. Most of it, however, consists of irregularly intergrown and overlapping grains of feldspar from which it is quite difficult to differentiate or to extinguish a single grain. From the general character of the section it seems that the feldspar has been remolecularized or reorganized which causes the mottled appearance as shown by the picture (Plate V, B). The feldspar is essentially orthoclase although it is quite probable that much of it is a semi-observed micropertthitic intergrowth of orthoclase and either albite or oligoclase. The plagioclase crystal shown in the center of the picture is albite with an extinction angle of 16° - 17° . Other parts of the section show definite grains of orthoclase mixed with much plagioclase and less quartz. The plagioclase fragments show extinction angles varying from 0° to about 18° which indicate the presence of plagioclase in all proportions from pure albite to oligoclase and some of it becoming alkaline enough to approach andesine.

There are a few flakes of primary muscovite but no prominent accessory minerals. Both the alteration processes, kaolinization and sericitization are quite evident. There is a thin film of sericite bounding many of the irregular feldspar particles and often it is this sericite alteration which determines the limits of a particular grain. Much of the feldspar shows a coating of kaolin. A few fragments of albite are nearly entirely obscured by secondary alteration whereas a great many of the detached particles of orthoclase are unusually fresh. Whatever the process may have been by which the reorganized appearance was caused it seems evident that the resultant rearrangement is more easily susceptible to alteration than the undisturbed particles. Despite all the evidence of metamorphism the section shows no fracture lines, but, on the contrary, is quite compact.

A more thorough study of the relation of the remolecularized feldspar to the rest of the dike is necessary to show the exact character of the spar which was marketed although it was evidently a mixture of orthoclase with the soda plagioclases, albite and oligoclase.

Other openings. About 500 feet south of the Brandywine quarry and on the same side of the road is a much smaller pit, and between this locality and the road corner $\frac{1}{4}$ mile south several narrow stringers of pegmatite are exposed in the road. South from the Brandywine quarry about 200 yards across the hollow on the east of the road is a trench driven S.30°W. about 150 feet between vertical walls of serpentine about 12 feet apart. This trench apparently followed a spar vein that began to narrow at the south end and so was abandoned. At

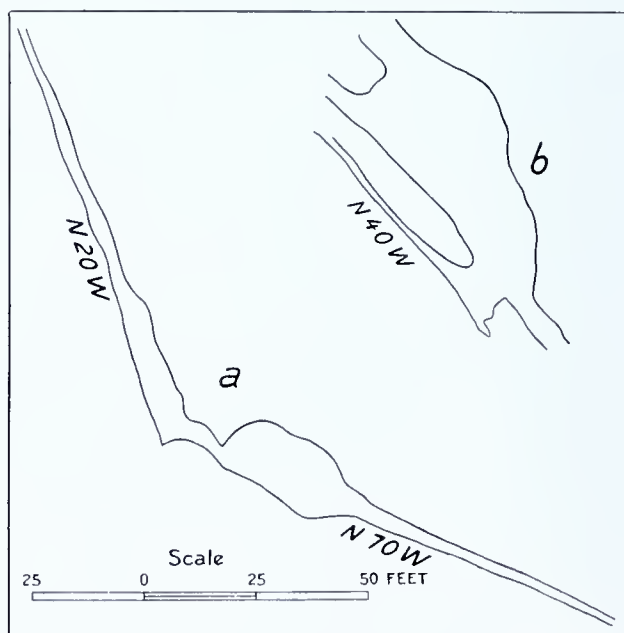


Figure 3. Outline of feldspar quarries in The Barrens showing different courses of dikes

the face the trench is about 20 feet deep and partly flooded. East from the Brandywine quarry about 100 yards and across the hollow is another pit 60 feet long and of irregular width up to 25 feet on a vein which extends in a $N.40^{\circ}W.$ direction. From the shape of the opening it may be assumed that there was here a lens 20 or more feet wide which tapered at both ends to only 2 or 3 feet. The pit is full of water and the walls rise vertically 10 feet or more above it so that the ledge could not be examined in detail. Parallel to it and on the south side only a few feet away a vein about 2 feet wide was mined for an equal length (Figure 3).

In this same locality on the north side of an east-west road and be-



Plate VI. Feldspar pit near Cooper log house in The Barrens, showing swell and pinch of the dike

tween the road and Black Run are several other small feldspar quarries on the property of Mr. Harry Rhodewalt consisting of 425 acres. The largest of the pits on this property is about 0.3 of a mile northeast of the before-mentioned cross-roads and 200 yards north of the east-west road. This old pit lies just north of a log house known as the Cooper place. Here a vertical vein ranging in width from 2 to 12 feet or more was developed for 225 feet. The vein and the pit make a sharp bend from a $N.70^{\circ}W.$ course to $N.20^{\circ}W.$ (Figure 3a and Plate VI).

The vein appears to dip northeast below the water which fills this long narrow excavation. The large dumps at this locality are being moved for road metal. Three hundred yards $N.60^{\circ}E.$ from this pit is another one 25 yards long on a curving vein swelling to about 10 feet and pinching at the ends. Some good spar was found on the dump and

also some with a considerable quantity of muscovite and biotite. The walls above the water which fills the pit are nearly vertical so that the vein could not be examined. Between these two pits north of the Cooper log house are several smaller ones all of which found spar. These are trenches up to several rods long on veins mostly under 5 feet in width. Besides the spar there is in this immediate locality some sugary quartz that has been screened for building sand and a considerable quantity of iron gossan was noted. Just east of these pits and on a small branch of Black Run is an old serpentine quarry about 200 yards north of the Martin Ferguson house. This quarry furnished the serpentine used for building the Presbyterian Church at Nottingham. This church was erected in 1878. The stone used in the William Galbraith house on Mt. Vernon Street, Oxford was taken from this quarry in 1927. The quarry face is about 25 feet high and 60 feet long. A 2-foot spar vein extending across the quarry has been left standing as the quantity and quality did not justify mining it. Still farther east on the Rhodewalt property is a pit called the Jones quarry because that is the nearest house (Plate VII). This is

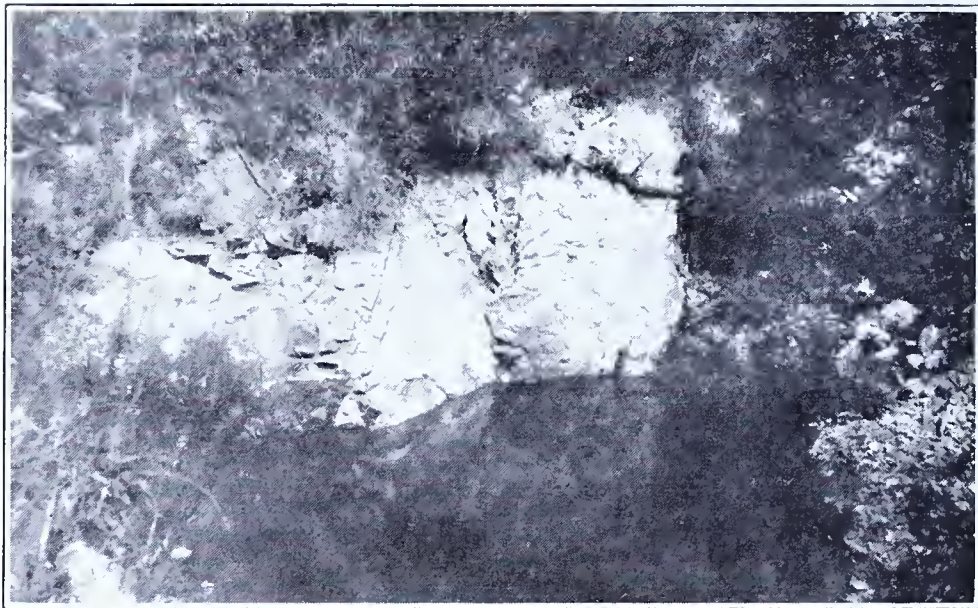


Plate VII. Abandoned pit in The Barrens near Sylmar, Chester County showing spar vein

about 400 yards north of the Cooper school. It is also full of water and is said to be at least 20 feet deep on a vein running $N.30^{\circ}W.$ The vein as exposed now is about 5 feet wide at the southeast end of the quarry and 8 feet at the northwest end, but apparently swelled to 15 feet in the middle. White albite is exposed at both ends at present. A small cross vein having a north-south course was dug to the north until it pinched to two veins only a few inches wide. It is understood that this opening was made by the Brandywine Summit

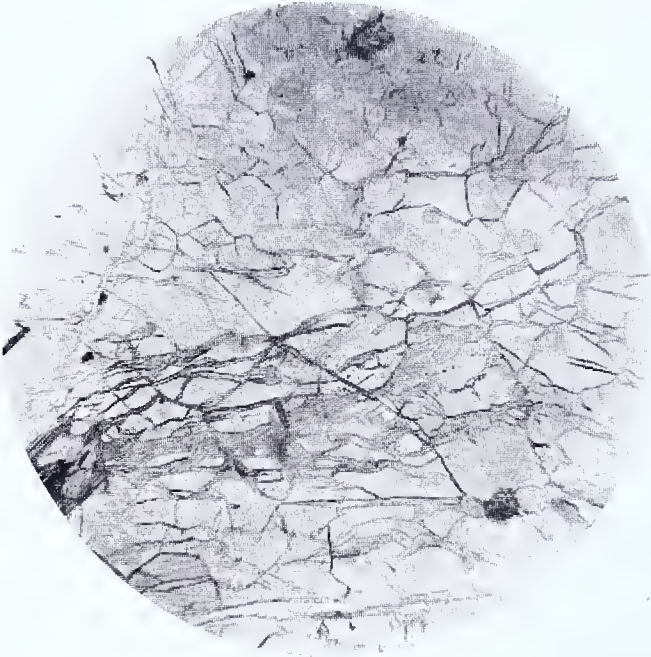
Feldspar Company. At the north end of this pit Mr. Rhodewalt has recently made an opening about 5 feet deep and is screening out some good spar. He has taken many tons of No. 2 spar from the dump of the old working and is still shipping from it. This second grade spar rejected by the original operators as not suitable for pottery finds a market in the manufacture of linoleum. Both muscovite and biotite occur here and a mass of tourmaline about 3 inches across composed of many small black crystals, was seen. Along the strike to the northwest in a distance of 1,000 feet there are two or three other pits which seem to be on the same vein. One of these is nearly circular and about 75 feet across, revealing a spar vein several feet wide; another is a trench on a vein apparently 8 feet wide but pinching out at the north end. A third trench on the north side of a little gully discloses a similar swelling from 1 to 5 feet between serpentine walls with white talc between the spar and the serpentine.

Specimens collected from the railroad platform at Sylmar represent material recovered by Harry Rhodewalt from waste dumps at the Brandywine and near by spar pits. The thin section of one of these samples consists of a highly fractured mixture of orthoclase, plagioclase, and quartz along with considerable quantities of biotite and a comparatively high percentage of secondary sericite. The maze of cracks, all of which are filled by sericite and kaolin, is shown by the picture (Plate VIII, A). The rock has evidently been subjected to high pressure which has caused crushing but which has not been sufficiently great to cause banding or other metamorphic equivalents. Alteration is confined to the cracks, with the centers of the feldspar fragments remaining unusually fresh considering the disturbance. The plagioclase particles show extinction angles varying from 0° to about 12° which indicate the presence of albite and oligoclase in several proportions although the majority of the fragments seem to be oligoclase (Plate VIII, B).

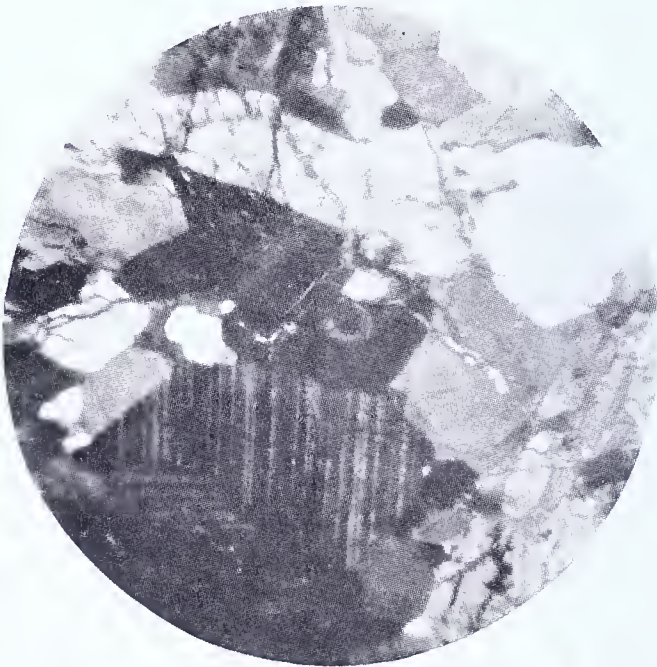
There is more plagioclase than orthoclase, the total feldspar content being about seventy per cent. The other thirty per cent consists of about two-thirds quartz and the rest of biotite and sericite with a few flakes of what appears to be primary muscovite. This material, regardless of its shattered and altered character, is fairly representative of the feldspar quarried at numerous places in southeastern Pennsylvania; that is, a mixture of orthoclase and plagioclase in varying quantities, some quartz, and a few flakes of mica. The comparatively high percentage of biotite is undesirable but it is possible that other sections might show a smaller quantity.

Another sample from this property, which was taken from a shipment at the railroad station is entirely unlike the one just described. The rock specimen itself consists principally of a light brown earthy-looking mineral grading to blue which resembles chaledony excepting

PLATE VIII

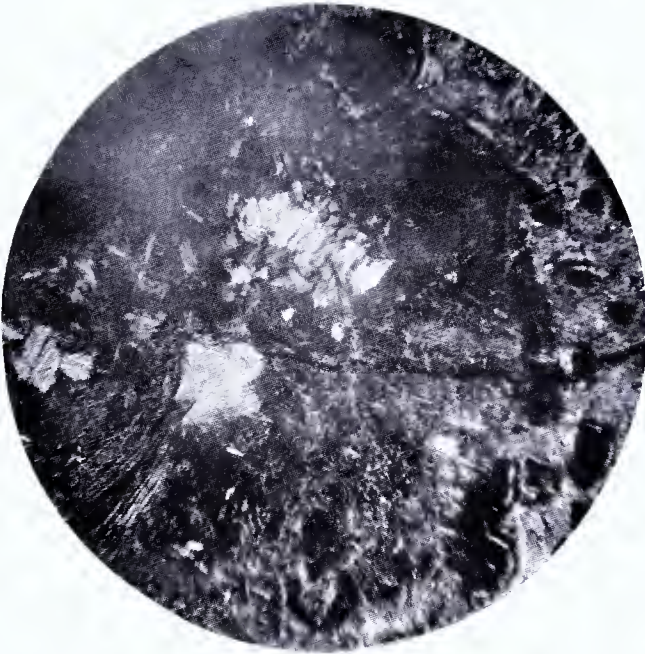


A. Pegmatite; shattered, showing sericite and kaolin development along fractures. Rhodewalt quarry, Chester County, Pennsylvania. X80 Exposed ten minutes, artificial light

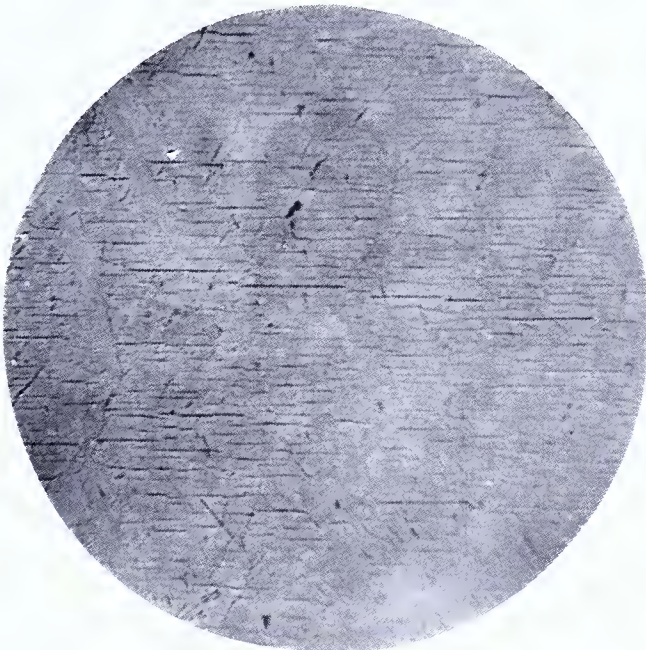


B. Albite-oligoclase; with orthoclase, quartz, and possibly cryptoperthite. Rhodewalt quarry, Chester County, Pa. X80 Crossed nichols. Exposed ten minutes, artificial light

PLATE IX



A. Colorainite; a few flakes of mica. Rhodewalt quarry, Chester Comty, Pennsylvania. X80 Crossed nichols. Exposed ten minutes, artificial light



B. Orthoclase; showing prominent cleavage cracks. Meredith quarry, Chester Comty, Pa. X80 Exposed eight minutes, artificial light

that it is softer. Shannon has identified it to be colorainite. It is impregnated with rods and needles of black tourmaline. Such an occurrence in a pegmatite dike is somewhat unusual and indicates the alteration of albite or oligoclase to colorainite. Unfortunately, this material could not be located in place so an accurate description of its occurrence is impossible. The thin section consists principally of a nearly structureless mass of what resembles typical secondary minerals (Plate IX, A). The light colored fibrous material near the center of the picture shows wavy extinction while the curved appearance near the edges is indicative of conchoidal fracture; both of these characteristics are typical of chalcedony, and in thin section the colorainite might easily be mistaken for it. Nowhere in the slide is it evident what the original mineral may have been nor is there any trace of feldspar in this particular section. There are a few scattered flakes of muscovite which are probably primary. Small quantities of this mineral would probably have no appreciable effect on the quality of the spar, but it is evident that a high percentage might materially change the nature of the material.

London Grove-New Garden Townships

Another group of feldspar quarries occurs within a radius of two miles of Avondale in London Grove and New Garden townships. The feldspar in these deposits is of the potash variety rather than soda spar as is common in the vicinity of Nottingham. Microcline is the principal feldspar present. Of the six or eight deposits in this vicinity only one is operating at the present time.

Avondale. On the Lewis Good farm on the west branch of White Clay Creek 250 yards north of the public school in Avondale, spar has been dug from a large body of decomposed pegmatite. The rock is so soft that it can be dug with a pick, and is so granular that some is used locally for building sand. A small excavation in the creek bank shows at least 10 feet of the dike and the cut bank above uncovers about 20 feet more. It is reported that years ago some Italians drove a tunnel 30 to 40 feet in this dike, all in soft spar.

The soft pegmatite contains large crystals of flesh-colored microcline, smaller ones of white spar, possibly albite, and a considerable quantity of muscovite.

This location seems to be the same as that described by Hopkins¹, in 1898 as owned and operated by Eugene Monahan. He says: "In the upper ten feet the spar is much decayed and mixed with considerable kaolin. Some crystals of black tourmaline have been found and large quantities of muscovite occur with the spar at the north end of the quarry. The vein varies in width from a few feet to thirty-one feet. This quarry produced between six and seven tons of feldspar per day during the summer of 1898. Monahan has been operating

¹ Hopkins, T. C., op. cit., page 16.

this quarry since January, 1897, before which date it was operated by other parties. He has also opened another spar quarry about half a mile north of Avondale, from which he shipped considerable feldspar in 1898. It produced at the rate of about 100 tons per month."

Baker quarry. Close to Baker Station, $1\frac{1}{2}$ miles northwest of Avondale, what is probably a single pegmatite dike has been opened in two or three places. On the property of the Pennsylvania Marble and Granite Company and just south of the large marble quarry a deposit has been worked until a pit about 50 by 30 feet and 25 feet deep was developed. This is on a pegmatite dike which appears to be about 25 feet wide, strikes N.75°E. and dips about 50° to the south-east. The pegmatite is fine-grained gneissic and contains much quartz and white mica. The crystals of feldspar tend to be lenticular in shape and few of them are more than 3 or 4 inches across. Muscovite plates in their largest development are not over $1\frac{1}{2}$ inches across. Biotite is abundant in bands which are commercially worthless. Most of the quartz is in irregular intergrowth with the feldspar and no pure masses over a foot across were observed. It is reported that this quarry was equipped with a derrick and steam hoist and that 16 men were employed about 1907, since which time the quarry has not been operated, and the faces are now largely concealed by wash and brush.

A few rods east of this opening and presumably on the same dike, Mr. Robert R. Jacobs of Toughkenamon is now operating a quarry with a development about 100 feet long and 50 feet across the floor on a dike about 40 feet wide. This quarry was opened about 15 years ago on the property of the Bondholders Committee of the Pennsylvania Marble and Granite Company. Here the dike runs N.65°E. and dips south about 30°. Both of the walls are covered with wash and the character of the country rock was not determined. It may be black and white mica schist, fragments of which were found in the adjacent cornfield. The dike is so soft that it is worked with pick and shovel even at the present depth of about 15 feet below the surface. From 1 to 3 men were employed here in 1927, using wheelbarrows to move the spar across the quarry floor. The product is sorted by hand and stacked on the quarry floor so that it is washed by rain before it is hauled by automobile truck to the mill at Toughkenamon. The product would appear to be an inferior No. 2 grade. The spar is stored under a shed at the mill, and ground in chaser and tube mills to 85 per cent through a 325 mesh screen, according to Mr. Jacobs.

The thin section of the product of the Baker quarry shows, principally, a fresh surface of microcline with remarkably well developed gridiron structure. There are a few included quartz fragments which have a rather irregular boundary with the microcline. There are two quite interesting features shown in the section: first, the interspersed

of patches of micropertthite with the microcline and, second, a crack which has been filled with small crystals of microcline.

About ten per cent of the section consists of irregularly shaped blotches of a cloudy micropertthitic intergrowth which seems to have been injected into the microcline at some time subsequent to its primary crystallization. These patches vary in size from sub-microscopic particles to large altered masses covering half the field of the microscope, and always show the same orientation which is evidenced by simultaneous parallel extinction regardless of their size or shape. In general, they seem to occur along minute cracks and lines of weakness in the microcline which may have been caused by or before the crystallization of the micropertthite. At any rate, it is evident that due to this combination of micropertthite with the microcline the chemical analysis of any such material will show alkaline constituents not to be expected in unadulterated microcline.

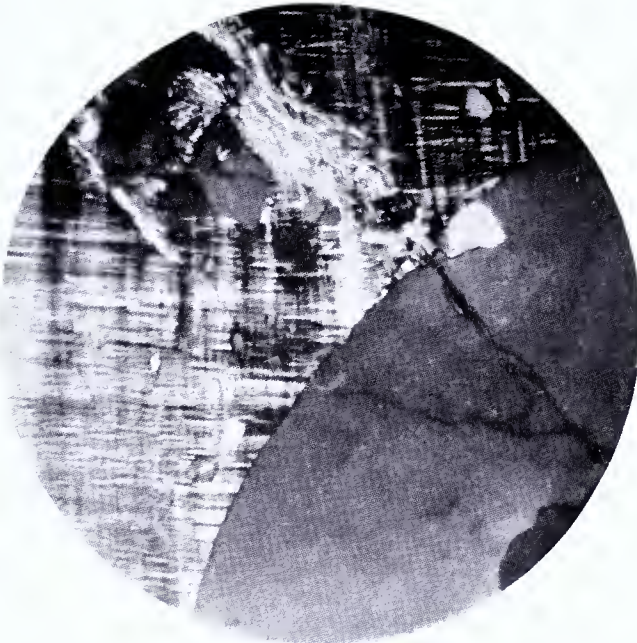
It is generally conceded that microcline is essentially a primary mineral. However, the fracture zone in the large fragment which has been subsequently filled by small crystals of varying orientation (Plate X, A) seems to be indicative of late crystallization in this crevice. The contacts are so distinct and undisturbed that it is inconceivable to assume that the small fragments are shearing debris of the large ones, particularly since there is no evidence of strain in the rest of the section. It seems that the crack must have formed immediately following primary crystallization when the residual magma was still of the proper composition to cause the crystallization of these smaller particles; or, there may have been disturbance along this zone just before final consolidation which would break up the large crystal but not the crystalline structure. In any event, the occurrence causes no change in chemical analysis or ceramic value but, scientifically, it perhaps merits further investigation.

The quarry material is a comparatively fine grained mixture of microcline, quartz, and muscovite. This thin section is probably typical of the feldspar content but it does not indicate the percentage of microcline to the other minerals.

Hicks quarry. Three-quarters of a mile northeast of Bakers and 1½ miles northwest of Avondale on the Hicks farm, a number of narrow pegmatite dikes were opened about 1899 at the forks of a small run. This locality is about half a mile north of the Thompson quarry and on the north side of a wood lot. The present development is a group of four pits within a radius of 50 feet on weathered banded pegmatite striking N.55°E. and dipping south 45°. The walls of the deposits are not exposed. The rock is so deeply weathered that it can be dug with pick and shovel. It is screened for building sand which appears to have been the latest use. Crystals of microcline up to 2 or 3 inches in diameter are scattered along the banding in the peg-



A. Microcline; with fracture zone filled with small crystals of microcline. Baker quarry, Chester County, Pa. X80 Crossed nichols. Exposed twelve minutes, artificial light



B. Microcline; with large quartz fragment, and well developed sericite alteration from orthoclase. Cooper quarry, Chester County, Pa. X80 Crossed nichols. Exposed twelve minutes, artificial light

matite. This banding is made conspicuous by muscovite which is unusually abundant. Occasional lumps of spar the size of a cocoanut can be found. Albite is perhaps more abundant than the microcline but it is fine grained. Watts says of this deposit: "Both the albite and the microcline pegmatite are contaminated by small flakes of biotite, but the exposures are merely in the capping of the dikes and cannot be taken as indicative of the composition at greater depths. The microcline pegmatite is composed of a mixture of buff and salmon feldspar and gray quartz, and a sample of this pegmatite was taken. It could not be cleaned of its biotite content but was tested for deformation range which was found to be 1285° to 1290° . The impurity present produces on fusion a yellow glass containing a large amount of undissolved biotite."

Thompson pits. On the Chatham road $1\frac{1}{4}$ miles northwest of Avondale and 200 yards beyond a school house is a line of pits on a pegmatite dike extending in a $N.55^{\circ}E.$ direction for at least 600 feet from the road. The pit nearest to the Chatham road is the largest but it, like all the others, now is shallow, with the sides washed in and overgrown with briars. Many of the pits are about 20 feet in diameter and now only 5 or 6 feet deep. One pit is said to have been 60 feet deep. This must have been near the road by the old waste pile. Bed rock is not exposed at present but the dumps show granular pegmatite like that at the Hicks quarry and lumps of good pink microcline can be found. This property has been idle many years and presumably the feldspar is practically exhausted. These pits were operated about 1898 by J. M. Thompson for the Eureka Mining and Operating Company of Trenton, New Jersey. Bastin¹ visited the property and describes the rock as "a granite pegmatite of fine grain and more or less gneissic texture due mainly to the concentration along certain bands in the rock of small muscovite plates, most of them under one-half inch across. No crystals of pure feldspar over 3 inches across were seen. The feldspar crystals are mostly lense shaped, with their long direction parallel to the gneissic structure." A few crystals graphically intergrown with quartz and some small garnets were found. Biotite appears to be entirely absent.

Cooper pits. The old Cooper pits are on a farm now owned by Penn Hoopes, $1\frac{1}{2}$ miles south of Toughkenamon and about the same distance west of New Garden. Three openings have been made on the strike of a north-south dike. The first pit is 250 feet north of an east-west road in a cultivated field 300 yards west of Hoopes' house. This pit is about 30 feet in diameter is used as a trash dump, and is marked by small fruit trees. The writer found graphic pegmatite, microcline, and quartz around the edge of the pit and in various places in the plowed field. About 1,000 feet north, on the north side of a

¹ Bastin, op. cit. p. 65.

wood lot, is a smaller pit showing the same minerals and 400 feet still farther north, on the north side of a small run, is a trench driven 25 feet into the hill. The face of this trench, originally 10 feet high, is now slumped, but the same minerals can be found on the dump. More quartz is in evidence here and in the run 100 yards on the west than elsewhere in this immediate locality. The quartz is milky and yellowish and in lumps a foot or more in diameter. The bed rock is not exposed in any of these openings. They may be on lenses in a single dike although this has not been definitely determined. None of these pits have been operated in less than 15 years. These deposits, however, were visited by Watts while bed rock was still exposed and he says of them,¹ "Both exposures show a pink microcline pegmatite containing smoky quartz and remarkably free from biotite or other iron-bearing impurities. Muscovite is present in very limited quantity. A white albite pegmatite is present and is confined to the regions along the walls of the dikes. The dike at both quarries is about 20 feet wide and has been opened for a distance of about 30 feet in each case. The south pit has been abandoned for some time and is partly filled by the caving of the walls. The north pit was worked recently and much good feldspar is in sight. The pink microcline pegmatite of this bed was carefully sampled and tested. It has a deformation range of 1280° to 1295° C. and fuses to a semi-transparent glass of a faint pink cream color."

The thin section of the specimen from the Cooper quarry is another typical microcline with a high percentage of quartz occurring as large fragments having a very sharp contact with the feldspar (Plate X, B). The patches of plagioclase and microperthite are again present, being particularly noticeable in fractured portions of the microcline. Alteration of the scattered orthoclase fragments has formed patches of fibrous sericite and kaolin which are unusually well developed. The microperthite has partially altered to kaolin with traces of sericite. There are a few scattered flakes of muscovite but no biotite or accessory minerals. Excepting the larger percentage of quartz this material, as shown by the thin section, is practically identical to that from the Baker and the Carpenter quarries.

In the highway along the township line on the east side of White Clay Creek just west of these openings and 100 yards south of a small branch of this creek the writer observed in a road cut an exposure of a spar deposit occurring in mica schist. This deposit shows for 20 feet on the east side of the road and barely at all on the west side. It dips to the south and on the upper side carries about 1 foot of quartz. The main deposit is white and pink spar and quartz with a considerable percentage of black mica in places. The accompanying diagram (Figure 4) shows this exposure as it appeared in September 1927 and

¹ Op. cit. p. 156.

indicates how a spar deposit of considerable size may lie close below the surface and yet not show at the surface.

Carpenter quarry. A feldspar deposit on the land of Moses B. Carpenter, $1\frac{1}{2}$ miles northeast of Avondale, was operated many years ago by the Pennsylvania Feldspar Company of Philadelphia. Development began here probably about 1890. Active quarrying ceased more than 20 years ago but the old dumps are worked over occasion-

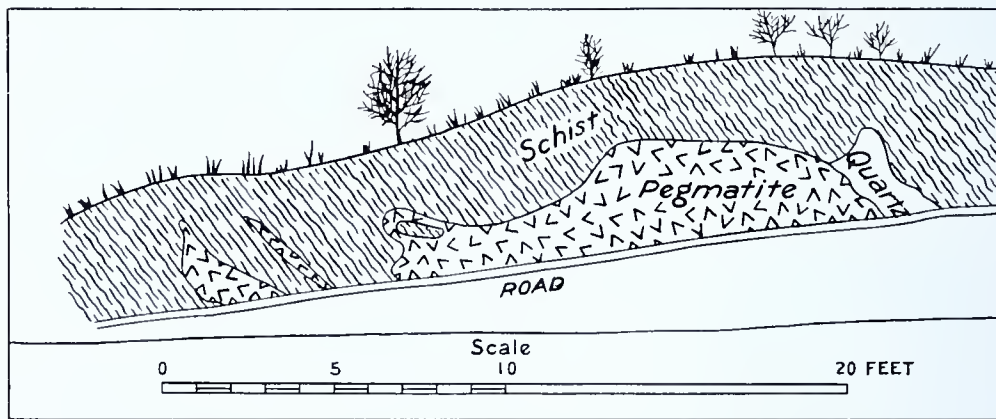


Figure 4. Diagram of feldspar deposit in road cut on White Clay Creek

ally at the present time for second-grade spar and for material to surface roads and walks. Apparently there was more than one dike here and some considerable excavations were made. Two large pits just west of the Carpenter house now contain locust trees up to 6 inches in diameter. Mr. Carpenter says that in the northern one of these pits there was a shaft 80 feet deep and that a hoisting engine, rails, and cars were used by the operators. A considerable quantity of No. 1 spar was produced from this deposit, a pegmatite dike consisting of a very coarse mixture of microcline and quartz. A stringer leading from the main pit to his house is reported by Mr. Carpenter to have been extra good spar. The few stringers exposed in the neighborhood are fine-grained pegmatite carrying a small amount of albite. Muscovite is present but biotite is practically absent in small flakes scattered through the pegmatite, but the writer saw one thin book of muscovite about 7 inches in diameter and one crystal of pink microcline about eight inches broad and 1 inch thick. These probably were unusual specimens saved because of their size. Watts collected a sample of the microcline pegmatite which was tested and found to have a deformation range of 1275° to 1290° C.; it fused to a semi-transparent mass of a pronounced cream color.

As shown by the thin sections there is little essential variation between the material from the Carpenter quarry and that from the Baker quarry which has been previously described. This section shows more quartz, not as small interspersed grains but as larger

fragments having a sharp contact with the microcline. There are a few fragments of muscovite but no noticeable biotite or secondary mica save for traces of sericite around the included micropertthite.

Some of the plagioclase in this section (Plate XI, A) occurs as definite crystals of oligoclase feldspar rather than as an intergrowth of plagioclase with orthoclase. Much of it, however, is the same micropertthite which is common to the microcline of southeastern Pennsylvania. Simultaneous parallel extinction is strikingly evident whether the included fragments are oligoclase crystals or micropertthite intergrowths. This seems to indicate that the micropertthite ratio of plagioclase to orthoclase is quite variable, ranging from almost pure plagioclase to a balanced mixture or even further to the other extreme of pure orthoclase, as shown by the Carlsbad twin (Plate XI, B).

Here again, the admixture of oligoclase and micropertthite may influence the chemical analysis and ceramic value of the microcline which is thought to be mineralogically pure.* Mr. Carpenter says that he used to sell selected spar by the barrel to makers of false teeth.

One hundred yards north of the Carpenter house on the east hill-slope considerable work was done on another pegmatite dike. The bank, however, is now washed down. East of the Carpenter house 1,000 feet in the corner of a patch of woods surface spar has been dug and shipped and in the hollow deeper in the woods a shaft was sunk 80 feet on spar. Water could not be kept out of the shaft so it was filled and the surface spar exploited. On the dump at this place one can now find excellent specimens of microcline, some with black tourmaline, and muscovite crystals 2 to 4 inches in diameter.

Jenkins quarry. On the Jenkins farm 1 mile north of Toughkenamon and one-third mile east of Carpenter's a pegmatite dike which strikes east and west and dips southeast was opened for spar. The quarry is on a north slope and exposes the dike for a distance of about 50 feet. In 1927 the opening was largely filled and only occasional pieces of the dike could be found in the field. Watts says of this deposit:¹ "The feldspar is chiefly coarse buff and salmon microcline pegmatite, with a small quantity of white albite pegmatite. Very little massive quartz is noted. The chief impurities are the micas. The albite pegmatite contains small flakes both of muscovite and of biotite, whereas only muscovite is noted in the microcline pegmatite, and it is confined to limited zones. This quarry was inactive at the time of visiting. The microcline pegmatite was sampled and tested. It has a deformation range of 1280° to 1295° C. and fuses to a transparent mass with a faint yellow tint."

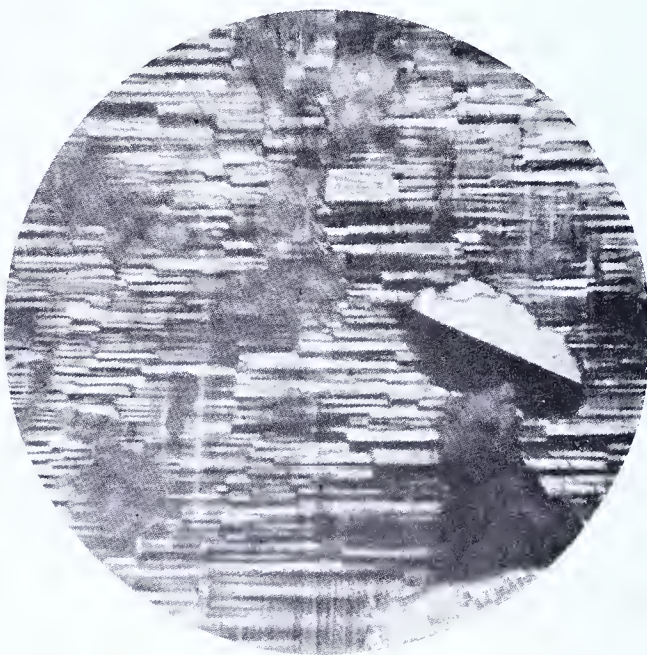
Chatham quarry. Barely three-quarters of a mile due north of Chatham on the east edge of a road and on land owned by the Order

¹ Op. cit. p. 153.

PLATE XI



A. Microcline; with large fragment of oligoclase, and injected microperthite. Carpenter quarry, Chester County, Pa. X80 Crossed nichols. Exposed fourteen minutes, artificial light



B. Microcline; with Carlsbad twin of orthoclase, and irregular patches of injected microperthite. Carpenter quarry, Chester County, Pa. X80 Crossed nichols. Exposed eight minutes, artificial light

of Maccabees (formerly the Louis Hammam farm) is a pit about 100 by 120 feet and with a rock face 30 feet high. The bottom of the pit is filled with water. Along one face of the quarry, bedding in the schist is nearly flat but over the water and in the deepest part of the pit it forms a low arch. Small stringers of spar parallel the bedding in the quarry face. As the main deposit of spar is below water it seems likely that these small stringers must have been found in the road cut and prospecting on them led to sinking a shaft which eventually disclosed the larger deposit. The writer found in the quarry lumps of microcline intergrown with quartz and abundant large lumps of milky quartz. This quarry was operated by the Brandywine Summit Kaolin and Feldspar Company. Bastin examined this deposit many years ago and says of it:¹ "The rock is a typical granite-pegmatite. The quartz is white and occurs in large, pure masses, and also irregularly intergrown with feldspar. Graphitic granite was not observed. The feldspar is pinkish-gray microcline, the largest crystals being 1 foot across, though most of them are smaller. The greater part of the material quarried is an irregular intergrowth of quartz and feldspar through which minute mica plates are scattered. Biotite is the principal iron-bearing impurity. The pegmatite here worked is a more or less flat-lying mass, at least 25 feet thick, the base being nowhere exposed. It has been worked from an open pit about 100 feet long by 80 feet wide by 40 feet deep, and in the wall of this pit the pegmatite is seen to be overlain by mica schist. From the southern end of the open pit a tunnel 12 feet high, 20 to 25 feet wide, and 40 feet long was being driven at the time of the writer's visit in May, 1907. The pegmatite in part follows the foliation planes of the schists, but also at many places cuts sharply across them. It is estimated that about one-half of the material quarried is ore and one-half waste. The quarry is equipped with steam pump, steam hoist, and derriek, and about 15 men are usually employed. Future working must be mainly by tunneling, and there is some question whether this could be profitably conducted for any great distance with material of this kind."

The appearance of the pit and the fact that it has not been worked for many years suggests that Bastin was right in his conclusion. Any further production of feldspar in this particular quarry would necessitate pumping to get rid of water and working by underground methods. The immediate neighborhood has been prospected for spar, as is indicated by small pits, now partly eaved, in the meadow on the opposite or west side of the road.

Lafferty quarry. On the Michael Lafferty estate, which is on the Wilmington pike southeast of Kaolin and about 4 miles south of Kennett Square, a spar pit was opened about 1915. It is on the edge

¹ Op. cit. p. 65.

of a wood lot 0.2 mile south of the house, $\frac{1}{2}$ mile from the pike and only a few rods from the Delaware State line. A trench was driven about 30 feet making a face 10 feet high, which exposes the graphic pegmatite in a solid ledge striking north and south and dipping east 12° . The country rock is a black gneiss. The trench is so narrow that at the depth opened there is no room to work and it is not developed enough to show the character of the dike. An impression was received that it may carry too much mica and quartz to be commercially satisfactory. It is reported that a carload of spar was taken from this deposit in 1926 by Golding and Son Company. It may not have proved satisfactory for no work has been done here since and the pit is now mostly washed in.

Evidently this deposit was much better exposed when visited by Watts for he described it as follows:¹ "The dike here is about 30 feet wide and has been exposed to a depth of about 20 feet and for a distance of about 40 feet. The chief constituent of the dike is a pegmatite consisting of light cream microcline and clear quartz, and generally occurring as a finely crystalline graphic granite. Insignificant amounts of albite pegmatite were noted along the walls. The quarry is remarkably free from biotite and garnets, a small amount of muscovite being the only associated mineral noted in the pegmatite. Numerous outcrops of similar microcline pegmatite were noted in the vicinity of this quarry. The graphic granite in the quarry was sampled and found to have the following chemical composition:

Composition of graphic granite in Lafferty quarry.

	per cent
Ignition loss	0.30
SiO ₂	72.39
Al ₂ O ₃	15.57
Fe ₂ O	20
CoO	.13
Na ₂ O	2.27
K ₂ O	9.55
<i>Total</i>	100.41''

Embreenville

Embreenville quarry. On the north side of the Wilmington division of the Philadelphia and Reading Railway and 100 yards west of the station at Embreeville is an abandoned feldspar quarry. It consists of a circular pit about 75 feet in diameter and 40 feet deep in mica schist which strikes northeast and dips southeast at varying angles. The walls are now slumped and the writer did not discover any spar when he visited the locality in September, 1927. In the adjacent railroad cut veins of quartz 2 to 4 inches thick occur along the schistosity.

¹Op. cit. p. 151.

Development began here in 1885 on a 10 foot dike. The pit was started at the top of a hill and worked down to railroad level, leaving a wall of rock between it and the railroad. Access to the pit was by a cut on the north side. The spar is said to have been good quality. This quarry is on the land of the Bowers estate. Operation stopped about 1910, partly because of difficulty with water and partly because an Italian workman was killed by a fall of rock. There is said to have been plenty of spar in the bottom of the pit when operations ceased. The output was shipped to Golding & Son Company, Trenton. Bastin



Plate XII. Fazio feldspar quarry near Embreeville

did not visit this locality but quotes Hopkins who described it in 1898 as follows:¹ "The vein, which is about 10 feet thick, crosses the railroad and has been quarried on both sides of the railroad track. The vein appears to correspond in dip and strike to the garnetiferous mica schists in which it occurs.*** The spar is nearly snow white, slightly stained by dendrite markings in places. The analysis indicates a soda orthoclase with a slight admixture of a lime-bearing feldspar and con-

¹ Hopkins, *op. cit.* p. 15.

siderable free quartz.*** The continuation of this vein southwest from the quarry is distinctly shown by the numerous outcrops at different points along the line of strike, and the outcrop would indicate that other quarries might be opened with profit." Watts visited this deposit and says of it,² "The feldspar of this dike is albite, occurring with quartz as a pegmatite. No microcline is exposed."

Fazio quarry. One mile south of Embreeville on the road to Unionville a feldspar quarry was operated on land owned by Giovanni (John) Fazio. This quarry was opened in a small way several years ago and several cars were shipped but it was not until 1926, when the Standard Flint and Spar Corporation of Trenton, N. J., leased the property, that production became notable. Under the superintendence of A. E. Buzzo the quarry has been enlarged to about 75 feet in diameter with a vertical face 35 feet high, all in spar (Plate XII). In September, 1927, six men were employed regularly and spar was being shipped as fast as produced. The output for the year, about 35 cars, was shipped to Trenton where it was ground and blended with other spar for use in the manufacture of pottery and glaze on sanitary ware. In April, 1928, production had ceased either because of an over supply having been quarried or because of unsatisfactory results for there is still a large quantity of spar easily accessible.

The opening is on a west-facing hillslope and shows the footwall in decomposed mica schist. The hanging wall has not been reached. The spar is unlike that seen at any other quarry in Pennsylvania, not only in the massive character of the deposit but also the physical appearance of the spar itself. It has a uniform gray color with no definite granular structure so characteristic of common granite pegmatites. The principal feldspar is perthite in which the microcline seems to be more abundant than the albite and oligoclase. Some of it may be unadulterated microcline or possibly orthoclase but the perthitic intergrowth is far more plentiful. Quartz commonly occurs in graphic intergrowth with the feldspar. The chief impurity is yellowish-green muscovite which is mixed with the spar throughout the quarry. Black tourmaline is abundant, shattered crystals several inches in length being found along with an occasional garnet or fragment of green beryl.

One thin section of the material from the Fazio quarry is composed almost entirely of quartz in large grains, the interstitial space being filled with small interlocking quartz grains, fragments of plagioclase feldspar, and flakes of muscovite. Quartz makes up about seventy-five per cent of the section, from which it is evident that the section does not represent the typical product of the quarry. The feldspar which does appear is principally albite or the transitory stage between albite and oligoclase showing extinction angles which

² Watts, op. cit. p. 151.

range from 3° or 4° up to about 12°. A comparatively large quantity of muscovite is present but no biotite or accessory minerals excepting tourmaline which is quite abundant in one part of the section.

Another thin section is a piece of typical microcline full of scattered patches of injected micropertthite. A large crystal of albite included within the microcline makes up about ten per cent of the section. Neither section accurately represents the quarry product but a composite of the two would be practically equivalent to the material which has been quarried; perthite, in which the microcline is in excess of the albite and oligoclase; microcline; oligoclase; albite; quartz, occurring freely mixed with the spar; and a considerable quantity of muscovite.

The Standard Flint and Spar Corporation furnished the following analysis of this feldspar:

Analysis of feldspar from Fazio quarry, Embreeville

Silica	72.03	Magnesium	none
Alumina	15.71	Sodium	3.03
Ferric oxide	0.129	Potassium	7.59
Calcium	1.10	Loss on ignition	0.32

About a quarter mile across the hill northeast of the quarry and near the fork of the roads there is a small prospect pit also on the land of John Fazio. The pegmatite is probably a continuation of the dike exposed in the main quarry. The material is quite similar to that in the quarry save that the appearance is nearer that of typical microcline. If the dike is continuous across this hill it contains a large reserve of spar which is easily available.

Unionville

Five miles north of Kennett Square in the vicinity of Unionville several small feldspar quarries were opened many years ago and were seen by Hopkins at the time of his visit in 1898. They have been idle for a great many years and are now forgotten by most of the local residents. They can be described only by quoting Hopkins:¹ "Feldspar was quarried from four openings during the present season (1898) and there are not less than half a dozen other openings from which spar has been removed within the last few years. The quarries are comparatively shallow and indicate an occurrence of the feldspar in pockets rather than veins, although they are probably enlargements of veins, but the country rock has so disintegrated that the spar lies in the loose, disintegrated material, and the vein walls are not clearly defined. The rock is a mica schist bordering on serpentine, and some of the quarries are apparently within the serpentine area. Muscovite and biotite are quite abundant in places and there

¹ Hopkins, op. cit. p. 15.

is considerable diffused quartz, but no large masses were observed. A band of green serpentine occurs in one of the quarries, and tourmaline crystals are reported."

The only quarry in this vicinity seen by the writer is 3 miles west of Unionville and half a mile west of Upland on the Joe Sharpless farm. Here many years ago Italians opened a pit on a hillslope between the house and highway, following a spar vein in biotite gneiss. The trench was driven at least 50 feet into the hillside and considerable spar was shipped before the lens pinched out. The pit is now largely filled and overgrown with trees and part of the working is converted into a cultivated field. Fragments of flesh-colored and salmon microcline were found and quartz is fairly abundant. Mr. Sharpless states that a search was made for spar in the vicinity but enough could not be found to justify further operations.



Plate XIII. Feldspar quarry below house of Albert Walker near Mendenhall

Pennsbury Township

Walker quarries. Five miles east of Kennett Square and about 1 mile east of Mendenhall on the Albert Walker farm feldspar has been quarried in two places. One is on the south side of the road in the woods (Plate XIII). Although this quarry is of considerable size it is now inaccessible because it is filled with water and the most that can be learned of the deposit is by an examination of the dump on the opposite side of the road. Watts describes this quarry, which was abandoned at the time of his visit, as "120 feet long, 80 feet wide, and at least 50 feet deep, about 15 feet being under water. White albite pegmatite and a small amount of buff pegmatite show in the walls above the water line, and the dumps contain about equal proportions

of these two pegmatites.” This probably is the quarry mentioned by Hopkins as at Fairville, a small hamlet nearby.

About 300 yards southwest and on the west side of the Walker residence is another quarry which has not been operated for a number of years but is drained and readily accessible. This quarry is possibly on a continuation of the deposit in the other pit. At least the strike of the dike, N.60°E., is in that direction. The dike is about 25 feet wide and dips southeast 60° between walls of fairly black gneiss. The pit is about 100 feet long, 35 feet deep, and 40 feet wide at the top. The southwest end of the pit exposes a banded ar-

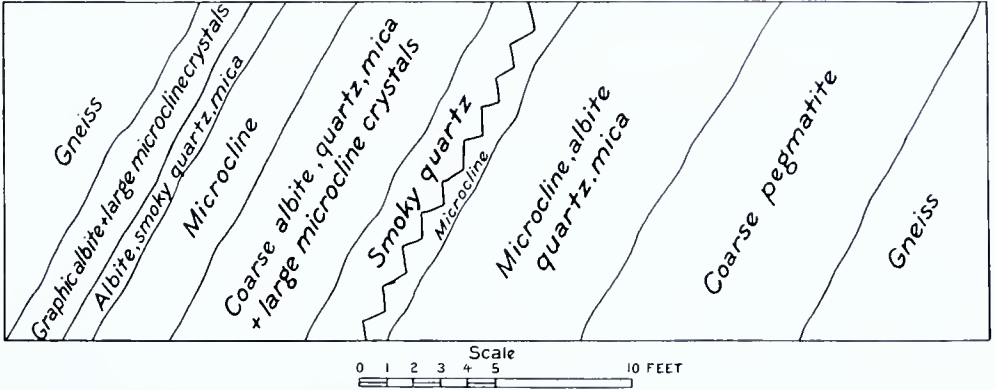


Figure 5. Diagram of feldspar dike in Walker quarry

rangement of spar and quartz as illustrated in the accompanying figure. The intergrowth of smoky quartz and large microcline crystals up to 1 foot in width is particularly noticeable (Figure 5 and Plate XIV). Large humps of clear microcline or dental spar can be obtained here. Watts describes this occurrence as follows: “The dike consists of a coarse mixture of pure buff microcline feldspar, buff microcline pegmatite, and white albite pegmatite. The upper strata are almost pure buff microcline, the middle strata buff microcline pegmatite, and lower strata are white albite pegmatite. The quartz in the pegmatite is clear but the deposit contains many lenses of granular smoky quartz. Muscovite in large and small “books” is very common, and to insure its elimination careful sorting will be necessary. Very little biotite or garnet and no tourmaline were noted in this quarry.” “The buff microcline of the pegmatite and the pure buff feldspar were tested and found to possess the same physical properties. The pure buff microcline has the following composition:

Composition of feldspar from Walker quarry

	<i>Buff microcline</i>	<i>Albite pegmatite</i>
Ignition loss	0.21	0.60
SiO ₂	64.36	67.93
Al ₂ O ₃	20.01	20.49
Fe ₂ O ₃	.20	.30

CaO	.46	2.60
Na ₂ O	2.48	6.95
K ₂ O	12.44	.80
Total	100.16	99.67 "

Mr. Walker states that quarrying stopped because of the low price and of the high cost of labor. There is nothing to indicate that the deposit is worked out and it is probable that a considerable quantity of mixed albite and microcline may yet be obtained from this deposit.

About half a mile still farther southwest on the Seth Rigby farm is a small pit along a run back of the house from which several cars

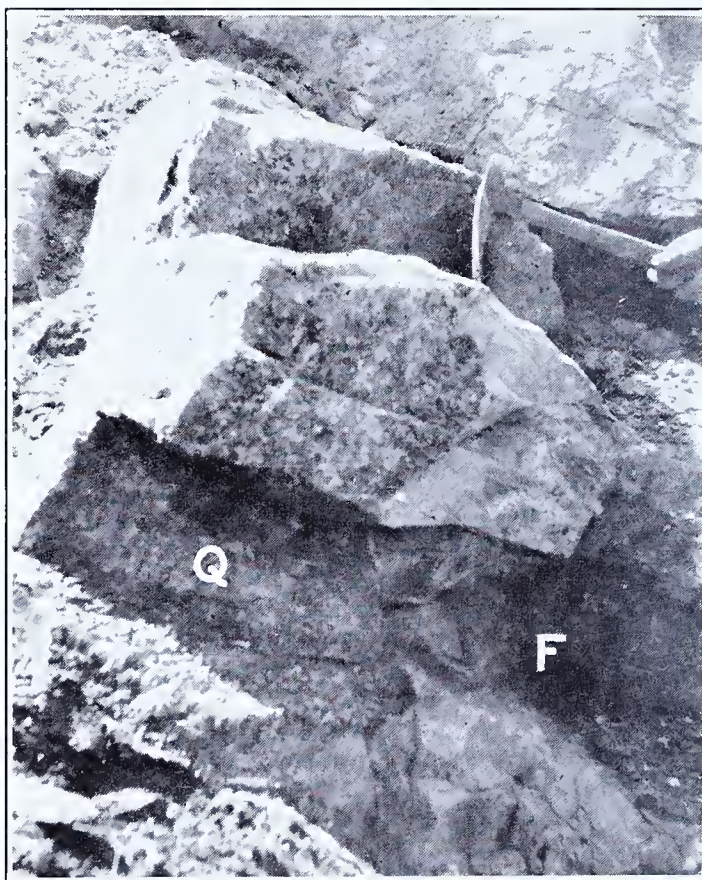


Plate XIV. Banded intergrowth of large crystals of quartz and feldspar exposed in quarry at the house of Albert Walker

of pottery spar have been shipped. The spar occurs in definite veins about 2 feet wide in schist. One vein is essentially microcline mixed with considerable quantities of quartz but no mica, and another vein is almost wholly orthoclase. Some of it is good dental spar. The material is quite similar to that at Walker's and the dike is probably

continuous from one farm to the other. Large quantities of spar are doubtless yet available in this locality.

The old Butler quarry is directly across the run on land now owned by David Ridgeway.. Nothing remains of it except a pool about 150 by 40, the banks of which are so overgrown with brush and vines that no outcrops are visible. The material which was quarried was practically identical to that in the Walker pits.

Stringers of pegmatite are exposed in a road cut 500 feet south of the railroad at Mendenhall (Plate XV). They may either indicate



Plate XV. Pegmatite stringers exposed in road cut 500 feet south of road at Mendenhall

the presence of an undiscovered feldspar deposit or may possibly be stringers from a continuation of the dike which has been opened on the Roberts and the Rigby farms.

COATESVILLE

Boyle farm. About $1\frac{1}{2}$ miles north of Coatesville on a branch of Rock Run feldspar has been produced on the Boyle and Thorne farm (Figure 6). The quarries on the Boyle Estate are in the woods 1,200 feet south of an east-west road and on the east bank of a small stream. The first pit was opened about 15 years ago on a mass of pegmatite with pink and white feldspar and black mica books 2 to 4 inches in diameter. The opening is very irregular in shape, in a steep hillside, with a face about 20 feet high. A new opening 100 feet west was made by a A. E. Buzzo in 1926 for the Standard Flint and Spar Corporation of Trenton, N. J., on a similar mass of pegmatite. This is a hillside opening 50 feet long, 20 feet wide, and with a face ranging up to 12 feet high. Massive quartz appears on both sides of the cut with a band of mica along the quartz. In September, 1927,

operations had been abandoned but a carload of spar remained on the stock pile. The producers say operations were discontinued because the spar is too high in iron to be suitable for their trade. The character of the wall rock and the course of the dike, if the deposit is a dike, were not determined.

Thorne farm. On the crest of a ridge on the north side of this same east-west road, quartz was dug and shipped 5 or 6 years ago from a massive vein on the edge of a patch of woods on the Thorne farm. Recently someone has sunk a pit on the very top of the ridge in the woods just east of this quartz vein and has disclosed a body of pegmatite. The opening is about 15 feet in diameter and 12 to 15 feet deep, a most precarious hole with the walls in imminent danger

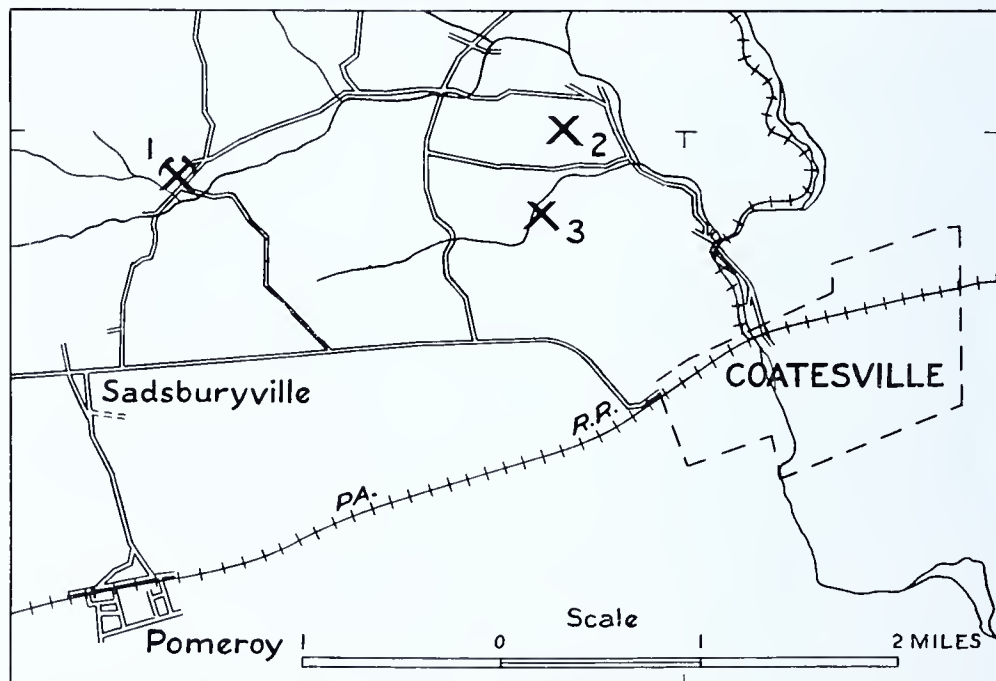
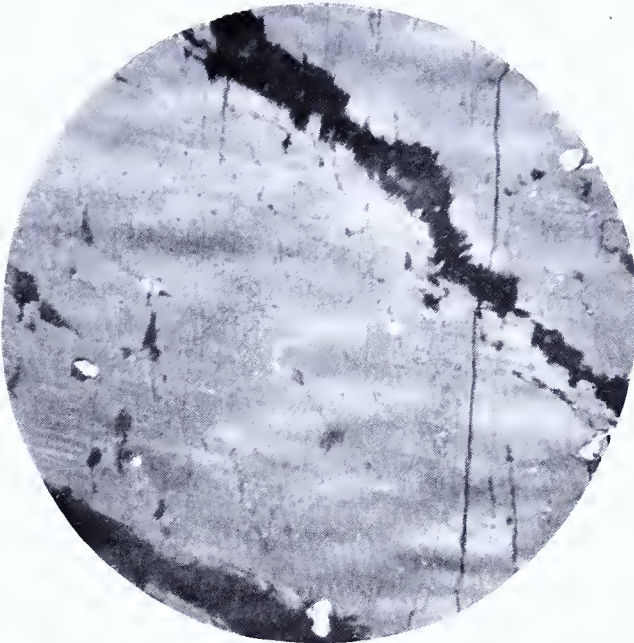


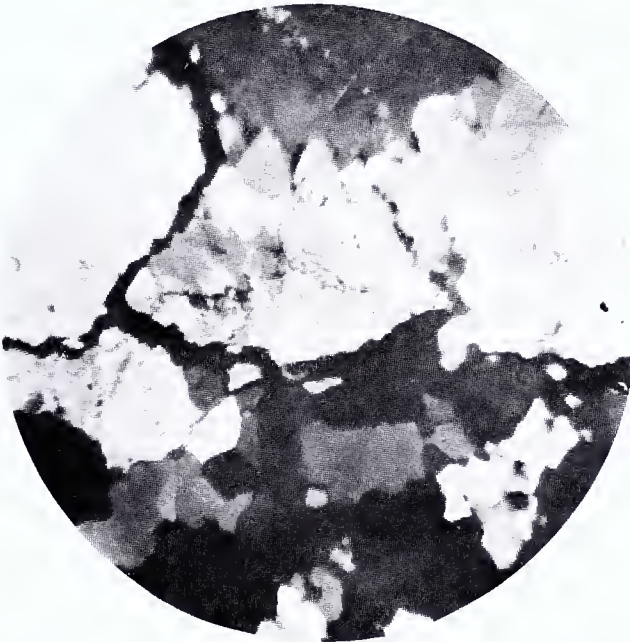
Figure 6. Map showing location of feldspar deposits near Coatesville, Chester County

of caving. A carload of sorted spar piled beside the pit shows some material of fair grade, much better than most of the rock seen in the walls of the pit. Most of that exposed in the pit is half spar and half quartz but the stock piles show some large crystals of albite. Further development is necessary to determine whether there is a commercial deposit at this place.

The thin section, representative of the material from the Thorne quarry, does not conform to the characteristics of orthoclase, of microcline, of plagioclase, or of microphertite (Plate XVI, A). It consists of a large fragment of feldspar which shows fine parallel cleavage cracks resembling the basal cleavage of orthoclase. There are several large nearly parallel fractures cutting across the primary feldspar which have subsequently been filled with feldspar of a similar nature



A. Cryptoperthite; fracture zones filled with injected material of the same nature; light spots are quartz. Thorne quarry, Chester County, Pa. X80 Crossed nichols. Exposed fifteen minutes, artificial light



B. Cryptoperthite; with interlocking quartz grains. Boyle quarry, Chester County, Pa. X80 Crossed nichols. Exposed fifteen minutes, artificial light

but with a different extinction position although all the filled cracks extinguish simultaneously. There are numerous sharply outlined quartz grains many of which occur in the large fracture zones. The entire field shows a tendency toward twinning striations but none of them are well defined; the result being wavy extinction over the entire section. This may indicate great stress which may have caused a partial transition from orthoclase to microcline and the resultant feldspar shows some characteristics of each. Also, there is a possibility that the original feldspar is not orthoclase but a cryptoperthite which is a molecular intergrowth of orthoclase with plagioclase in such a manner that the perthitic structure is too minute to be discernible even under high magnification.

There is practically no muscovite or other accessory minerals in the thin section and only a slight trace of sericite or kaolin. A chemical analysis of the material would probably show the equivalent of a mixture of orthoclase with a little plagioclase which would be quite similar to the analyses of the produces from other ceramic feldspar quarries. A further petrographic study of this occurrence would no doubt reveal interesting associations of the feldspars in perthitic intergrowths as well as the accurate interpretation of this section.

Part of the thin section of the material from the Boyle quarry is practically identical to that previously described from the Thorne pit; that is, large fragments of feldspar which is probably a perthitic intergrowth but the exact identity of which is questionable without a more detailed investigation. In addition, there are numerous particles of albite or albite-oligoclase; some orthoclase, shown by an occasional Carlsbad twin; and considerable quartz in the form of interlocking grains (Plate XVI, B). There has been some kaolinization but very little sericitization. Accessory minerals are scarce. The feldspar of this quarry, then, as shown by the thin section is approximately the chemical equivalent of a mixture of orthoclase and acid plagioclase. This section, like that from the Thorne quarry, seems to offer interesting petrographic features which warrant further study.

Meredith quarry. One of the few spar quarries still operating is the Meredith quarry, $1\frac{1}{4}$ miles northeast of Sadsburyville and 3 miles west of Coatesville. This quarry is owned and operated by Helen A. Meredith Co., Inc., of Coatesville, producing poultry grit and a cleaning compound for kitchen and bathroom. The poultry grit is made in two sizes, for adult fowls and for chicks. Very finely pulverized spar is made into cakes for use as a mild abrasive. Some of the quartz from this quarry is used by a dental supply company in the manufacture of false teeth. The mill is at the cross roads adjacent to the quarry.

In 1910 when B. F. Meredith was operating here the largest pit was 150 feet long from north to south and about 50 feet across, in an

irregular body of pegmatite. A short tunnel had been driven on the east. The long pit, sunk about 30 feet below the surface is now filled with water in its deepest part, but has been extended in a circle about 200 feet in diameter. In 1927 this circle was nearly complete, leaving a knob in the middle of the quarry.

The material being used is a coarse intermixture of feldspar and quartz which varies in color from salmon to gray. The principal feldspar constituent is microcline or orthoclase but some of it is probably in perthitic intergrowth with oligoclase and albite. Most of the quartz is transparent, white, or gray, but a little of it is noticeably smoky and a few pieces are pink. The quartz in the upper part of the dike occurs intermixed with feldspar as graphic granite, while farther down the mixture is coarser and more irregular. Quartz also occurs as definite veins cutting the pegmatite and in stringers shot through the country rock. Biotite and tourmaline are rare, but a light green mica is scattered through the dike.

As shown by the thin section the specimen from the Meredith quarry is a typical orthoclase (Plate IX B). The development of parallel cleavage cracks is the most evident feature of the feldspar. There are a few small included quartz grains as well as a series of fractures which have been filled by either orthoclase or cryptoperthite. This material is nearly identical to the main mass, the cleavage crosses it uninterrupted; but the extinction position is different although all the fracture veins extinguish simultaneously. Secondary alteration, both sericitization and kaolinization, has started to attack the feldspar perhaps more noticeably on the material filling the cracks than the main mass. Accessory minerals are quite scarce. This section indicates that there is undoubtedly good spar for ceramic use in the quarry which may some day be utilized.

In the deeper part of the workings now filled with water, veins of white and pink spar, probably microcline, have been reported. This material has not been worked in recent years because of the lack of sufficient demand for ceramic spar.

Quarrying is a simple process, the dike rock being blasted and barred down, loaded in carts by hand, and hauled to the adjacent plant, where it is crushed, screened and bagged. At the present rate of consumption there is enough material in sight to supply the mill for many years; and, if the reports are authentic, there is a reserve of ceramic spar below water level.

DELAWARE COUNTY

Brandywine Summit. In 1898 and for some years thereafter the Brandywine Summit Kaolin and Feldspar Company was the largest producer of spar in Pennsylvania. Production gradually declined and all operations ceased when the mill burned in 1920. The railroad spur has since been taken up and little remains to indicate the presence

of a former prosperous industry except the abandoned pits and a few neglected buildings. The quarrying operations of this company were quite extensive, including kaolin pits near the mill, large spar quarries at Elam, and the soda spar quarry in Chester County near Nottingham which has previously been described.

Large quantities of high grade kaolin were produced from the pits near the mill which was about 1 mile west of Elam and $1\frac{1}{2}$ miles southwest of Brandywine Summit. The kaolin had an excellent reputation on the market when washing was discontinued in 1891. For



Plate XVII. Pond filling Brandywine Summit kaolin pit

a few years after this the National Kaolin and Ornamental Brick Company continued using the waste clay from the dumps in the manufacture of ornamental brick. Quarrying was discontinued primarily because the best part of the kaolin near the surface was exhausted and water greatly hindered operations at depth. The bank of the pond which now fills the former excavation is so overgrown that little trace of the kaolin can be seen (Plate XVII).

After 1891 when the Brandywine Summit Kaolin and Feldspar Company abandoned the kaolin pits, the feldspar quarries about 300 yards southwest of Elam on the Worth place were developed. The excavations consist of three large partly connected open pits which are now abandoned and partially filled with water. The total development covers an area of about four acres. The eastern and oldest pit is a circular opening about 200 feet in diameter with a depth to water level of about 60 feet. It is said to have originally been about 200 feet deep and tunnels running off from the bottom penetrated the dike for 300 feet or more. Much of the dike material is orthoclase or orthoclase-albite intergrowth which is now weathered to a fine granular kaolin which contains fragments showing every transitory stage

from orthoclase to kaolin. A few unaltered pieces of buff microcline can be found and much muscovite but very little biotite. Huge masses of vein quartz are scattered around the pit. From the nature of the contacts between pegmatite and country rock shown around the sides of the excavation it seems that the remaining material represents stringers from the main mass which has been quarried (Plate XVIII).



Plate XVIII. Eastern pit of Brandywine Summit quarry at Elam showing white mass of weathered feldspar

The central pit is more extensive but less deep than the first but otherwise they are noticeably similar. The character of the pegmatite dike exposed in the eastern wall is ideally shown in the illustration (Plate XIX). The irregularity of the dike is striking; surface outcrop would in no way indicate the thickening at water level. The material exposed is principally orthoclase or perthitic intergrowth of orthoclase and albite intermixed with muscovite and quartz. There is very little microcline. Graphitic granite is exposed along the east side of this pit but none is seen elsewhere in the quarry. Much of the quartz is granular and upon disintegration resembles ice cream salt.

The westernmost pit is smaller than either of the other two and it has been recently worked principally for hand picked dental spar. It is now abandoned and filled with water. An old flume still in good condition was used to carry a small stream across the pit. One hundred or more bags of high grade spar are stored in a shack near the quarry. This material is practically unaltered (Plate XX). It

consists of orthoclase, possibly some microcline, and some perthitic looking material. The property was first developed by Edward Worth who sold his holdings to S. H. Lund who was interested in the Brandywine Summit Kaolin and Feldspar Company.

Bastin¹ describes the mill as it appeared to him in 1908: "The mill is located on a private spur of the Philadelphia, Baltimore and



Plate XIX. Central pit of Brandywine Summit quarry at Elam

Washington Railway, about a mile southwest of Brandywine Summit station. The process of grinding at this mill is similar to that used at most other feldspar mills, the material being first crushed in chasers and then ground in tube mills, the principal differences from other mills being in the use of a mechanical carrier for removing the crushed feldspar from the chasers and transferring it to bins over the tube mills, and in the use of large tube mills, instead of the small tube mills usually employed. It is said that these effect a considerable saving in power. A suction fan is also employed to collect fine feldspar dust, about one bag of this being obtained in the course of a day. This dust can be marketed for certain purposes, and the device serves to keep the mill much freer from dust than it otherwise would be and to make the work less disagreeable for the men.

Some soda feldspar from a quarry belonging to this company in Nottingham, Chester County, is also ground at this mill. This soda feldspar is burned in a kiln and cooled by a stream of cold water before crushing. This process fractures the spar and renders the crushing and grinding process less difficult. The potash spar is ground just as it comes from the quarry."

¹ Bastin, E. S. Feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, p. 71, 1910.

Darlington. A feldspar quarry 1 mile northeast of Darlington, or $1\frac{1}{4}$ miles east of Glen Mills and not far from Wawa, station on the Maryland division of the Pennsylvania Railroad, was mentioned by Bařtin as the Sharpless abandoned quarry. Watts says of this locality* that a shallow pit was dug into the dike for feldspar and was later worked for mica by means of shafts. "The workings have



Plate XX. High grade spar from Brandywine Summit quarry at Elam

been abandoned and the shafts filled with water hence no opportunity to study the dike is provided. About the entrances to the shafts are heaps of albite pegmatite and a small quantity of buff microcline. The albite pegmatite carries an excessive amount of quartz but the microcline is entirely free from quartz. The albite pegmatite has a deformation range of 1300 to 1305° C. and at 1310° C. fuses to a shapeless mass of enamel-like material. The microcline was sampled and analyzed showing the composition given in the accompanying table. It has a deformation range of 1280 to 1290° C. and fuses to a semi-transparent glass free from tint."

The writer was informed on his visit to this locality in September, 1927, that the only spar mine in that vicinity had been used as a trash dump for years and nothing further of mineralogical interest could be learned.

Chester Heights. A feldspar deposit long abandoned was seen by the writer half a mile southwest of Chester Heights railroad station and on the south side of the west branch of Chester Creek. This

* Watts op. cit. p. 145.

deposit is across the creek from and about 50 feet above a railroad and about 100 yards from a highway. Spar has been dug in several trenches close together on the steep hillside facing the creek. The dumps from these trenches are now being utilized for filling on nearby roads. The openings extend to the top of the hill 75 feet above the creek and on the west side of this hill a long cut was driven. So many years have elapsed since any mining was done here that the sides have slumped somewhat but at the head of the cut soft spar sand is exposed, apparently flat-lying. Only small pieces of spar remain on the dumps and little could be determined about the size of the deposit. As a matter of historical record Watts' statement concerning this deposit, which is on the land of Mrs. Charles Felger, is appended.¹ "The dike strikes northeast and dips southeast. It averages 20 feet in width and is exposed in the quarry for a distance of about 160 feet. A large proportion of the dike is an albite pegmatite, but toward the north end of the quarry this is displaced by a buff microcline pegmatite in which the quartz is of the smoky variety. In many places the dike contains streaks of chlorite, and the sorting of the feldspar must be conducted with care in order to eliminate this material and also to insure the complete separation of the buff microcline pegmatite and the white albite pegmatite. In the south end of the quarry the albite pegmatite is completely altered, resulting in a kaolin-like material, but lacking in plasticity. Small quantities of cream and salmon microcline were noted but not in commercial quantity. The various constituents of this dike are more or less segregated, thus simplifying quarrying, but the proportions of the different ingredients do not maintain sufficient uniformity to permit of a uniform material being obtained by taking the run of the quarry." Analyses of the microcline and albite pegmatites made from samples taken by Watts are given in an accompanying table.

Bunting quarry. On the farm now owned by H. E. Greene located 1½ miles northwest of Boothwyn on the middle branch of Naaman Creek is a quarry of some size that has long been abandoned but presumably produced considerable spar. Beginning close to the barn and extending in a northerly direction is a pit about 200 feet long and 20 to 30 feet wide full of water and overhung with brush. The depth is not known. A notable quantity of excellent pink spar occurs in the soil of the field lying between the barn and the road. If this did not come from the mining operation, it would seem to indicate the presence of another spar vein as yet undeveloped. In this same field muscovite in crystals up to 2 inches in diameter is abundant. Large lumps of transparent crystalline quartz occur also on this farm and near the feldspar quarry masses of small mica crystals weighing

¹ Watts op. cit. p. 146.

up to 200 pounds can be found. This locality is reported to have produced a high grade of potash feldspar but has been abandoned so long that information is indefinite as to whether the deposit was exhausted. The abundance of spar in the soil suggests the possibility that another dike might be found here. The deposit, however, is at least $1\frac{1}{2}$ miles from a railroad.

Halsey quarry. On the land of Dr. G. F. Baier, 1 mile northwest of Boothwyn and formerly owned by the Halsey family, feldspar was quarried many years ago. The opening is about 500 feet west of the house on the bank of a small creek in the edge of the woods. The pit is now filled with water and the banks overgrown with brush so that nothing could be seen of the ledge nor was spar found around the edge of the pit. However, farther up the hill and close to the road just west of Dr. Baier's house the writer dug through the turf and turned up fragments of good pink spar. This may have been lost from a passing wagon or it may represent the disintegration of some undiscovered dike. Watts says of this deposit: "The dike consists of a coarsely crystalline pegmatite similar to the Chester Heights quarry. The clean buff pegmatite and pure feldspar has all been removed from the quarry, and only a small amount of mixed pegmatite and some albite pegmatite is in sight."

Boothwyn quarry. Five miles west of Marcus Hook and half a mile southwest of Boothwyn just below where the road crosses the east branch of Naaman Creek a small dam has been built. In this dam are large humps of almost pure pink feldspar used as building stone. In the stone wall of the barn on the adjoining Boudwin farm similar large lumps of spar were used. This fact would lead a mineral prospector to look for a spar vein in this vicinity and a search should be rewarded for large pieces of feldspar are very abundant on both sides of Naaman Creek on the Boudwin farm. Feldspar was quarried here many years ago and hundred of tons have been shipped. The principal pit is on the east side of the creek and about $\frac{1}{4}$ mile south of the highway. This pit is now occupied by a pool of water about 100 feet long and 50 feet wide but little can be seen of the feldspar dike which is said to be nearly 40 feet wide. Watts says that the feldspar is a dark buff microcline pegmatite of which a great part is graphic granite. He found little mica and no black tourmaline in any of the exposed faces or on the dump heaps. Since his visit in 1915 both the ledge and the dumps have become covered with soil and overgrown with brush. In the cultivated field on the hill just above this pit pink spar and quartz are very abundant.

On the west side of Naaman Creek and about 150 yards southeast of the Boudwin house in a cultivated field is a pit 15 feet in diameter and 10 feet deep exposing a vertical dike of pegmatite 11 feet wide

consisting principally of microcline and pethite along with some orthoclase. Biotite, quartz and tourmaline are common. The wall rocks are black schist. The course of the dike is north and south. Excellent specimens of spar can be obtained at this pit and in the field for 300 to 400 yards north fragments of spar may be picked up at short intervals.

A small prospect pit in the field just west of the house shows high-grade spar which is probably orthoclase. It is now almost entirely weathered to kaolin. The extent of the material is unknown and further prospecting would seem to be warranted.

The surface indications suggest that spar is more abundant here than in any other locality in Delaware County and it would seem worthy of further prospecting. The location is within a few hundred yards of the Baltimore & Ohio Railroad at Ogden station, which is half a mile north of the Pennsylvania-Delaware State line.

Twin Oaks. About half a mile northwest of the Twin Oaks station on the Lewis Dutton farm a feldspar quarry was operated for a short time by Mr. Worth of Brandywine Summit. This pit is a narrow opening about 200 feet long and 20 feet deep. It has been abandoned for over 15 years and, consequently, the nature and extent of the pegmatite is obscured by caving and vegetation. The material on the dump is almost entirely weathered except for numerous fragments of microcline and many flakes of mica. The quarry product was undoubtedly a combination of microcline, albite or oligoclase, perthite, and possibly some orthoclase, all of which was mixed with quartz and mica. The further exploitation of this pit is questionable.

In 1908 about half a mile west of Twin Oaks station of the Baltimore and Ohio Railroad, and on the north side of the tracks the Twin Oaks Feldspar Company opened a quarry on the Frost place for potterly spar. The venture was widely advertised and in 1909 a few hundred tons of spar was sold, but in September of that year financial difficulties caused the property to be sold into bankruptcy. The quarry was afterwards worked for a short time by the National Spar Company. After the first small vein of good spar had been worked out, careful prospecting failed to reveal any other deposits which were clean enough to market without hand cobbing which was quite expensive.

The line of old pits extends along the railroad for about 350 feet. Trees 6 inches in diameter are growing in some of them. The nature of the material in place is obscured by talus and vegetation but the material on the dumps is similar to that at the Dutton pit; fragments of microcline, much mica, along with weathered spar which originally was probably perthite, with some plagioclase or possibly orthoclase. Several years after the quarry had been abandoned a small mill was constructed and the waste spar on the dumps was ground for chicken

grit. The immediate vicinity has been thoroughly tested for undeveloped spar deposits with no avail, hence, further supplies from this locality are improbable.

MONTGOMERY COUNTY *

A feldspar quarry on the east bank of the Schuylkill River between Lafayette (Miguon station) and Spring Mill, opened in 1886 and long abandoned, is the only one recorded in Montgomery County. Thirty tons of spar removed from it was sold to potteries in Trenton.

According to a contemporary description¹, the quarry was close beside the county road and two railroads, just north of a small tributary of the river and 100 yards south of a granite vein. The spar vein or dike was exposed for 45 feet and dipped N.40° beneath the gneiss. Instead of paralleling the foliation of the gneiss, it cut across the structure in a nearly north-south direction. Carter says: "The feldspar is orthoclase, of light pink color, with an occasional streak of white granular quartz running through it."

The writer was along the road in April 1929 and found humps of feldspar and evidence of slight excavation about 50 feet from the north side of the river road, one-fifth mile north of the railroad underpass, where three large granite blocks lie between the road and the railroad. The bedrock is schistose and the vein may have been 10 inches wide. Further information could be obtained only by digging. A bushel or more of spar lies on the dump in pieces the size of a cocoanut and football.

¹ Carter, O. C. S., Feldspar bed in Laurentian gneiss: Proc. Am. Phil. Soc. vol. 29, pp. 49-50, 1891.

